2023

GOODS MOVEMENT EMISSIONS INVENTORY

PORT HOUSTON℠

2023

GOODS MOVEMENT EMISSIONS INVENTORY

PORT HOUSTON[SM]

Prepared by

STARCREST CONSULTING GROUP, LLC

ENVIRONMENTAL MANAGEMENT · AIR QUALITY · CLIMATE · SUSTAINABILITY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The following companies and organizations assisted with providing the technical and operational information described in this report, or by facilitating the process to obtain this information. We truly appreciate their time, effort, expertise, and cooperation.

Alltrans Port Services
APS Stevedoring
Ardent Mills
Arrow Steel
BWC Terminals
C&C Houston Bayport LLC
Container Maintenance Corporation
Cooper-Ports America
Covey Transport
Dixie Cullen
Empire Stevedoring
Frontier Logistics
G&H Towing
Gulf Stream
Gulf Winds
Hansen Mueller
Houston Pilots
Houston Terminal LLC
Huntsman
Jacob Sterns & Sons
Jacintoport
Kinder Morgan
Port Terminal Railroad Association
Richardson Companies
Sesco Cement
South Coast Terminals
Steel Pipe Storage Processors
Terminal Link Texas
The Andersons
Tico Tractors
TPC Group
Turning Basin Service
Watco Companies

ACKNOWLEDGMENTS, CONTINUED

We would like to thank the following Port Houston's Environmental Affairs Department for assistance during the development of the emissions inventory:

Ken Gathright

Trae Camble

Kelli Gallagher

AUTHORS

Guiselle Aldrete, *Consultant for Starcrest*

Archana Agrawal, *Principal, Starcrest*

Kirsten Lopez-Palm, *Consultant for Starcrest*

Graciela Lubertino, *Consultant for Starcrest*

Jill Morgan, *Consultant for Starcrest*

CONTRIBUTORS

Steve Ettinger, *Principal for Starcrest*

Denise Anderson, *Consultant for Starcrest*

Eric Bayani, *Consultant for Starcrest*

Russelle Hansen, *Consultant for Starcrest*

Nohemi Taguite, *Consultant for Starcrest*

COVER

Melissa Anderson, *Principal, Starcrest*

PHOTOS

Port Houston, *media gallery*

ACRONYMS & ABBREVIATIONS

AIS	*automatic identification system*
ATB	*articulated tug and barge*
BSFC	*brake specific fuel consumption*
CF	*control factor*
CHE	*cargo handling equipment*
CH_4	*methane*
CO	*carbon monoxide*
CO_2	*carbon dioxide*
CO_2e	*carbon dioxide equivalent*
E	*emissions*
ECA	*emission control area*
EF	*emission factor*
EI	*emissions inventory*
EPA	*U.S. Environmental Protection Agency*
FCF	*fuel correction factor*
g/bhp-hr	*grams per brake horsepower-hour*
g/hr	*grams per hour*
g/kW-hr	*grams per kilowatt-hour*
g/mi	*grams per mile*
GIS	*geographic information system*
GHG	*greenhouse gas*
GMEI	*goods movement emissions inventory*
GWP	*global warming potential*
HDV	*heavy-duty vehicle*
HGB	*Houston-Galveston-Brazoria ozone nonattainment area*
HSC	*Houston ship channel*
hp	*horsepower*
hrs	*hours*
IMO	*International Maritime Organization*
kW	*kilowatt*
kW-hr	*kilowatt-hour*
lbs/day	*pounds per day*
LF	*load factor*
LNG	*liquefied natural gas*

ACRONYMS & ABBREVIATIONS, CONTINUE

LPG	*liquefied petroleum gas*
MCR	*maximum continuous rating*
mph	*miles per hour*
MMGT	*million gross ton*
MMSI	*maritime mobile service identity*
MOVES	*Motor Vehicle Emissions Simulator, EPA model*
N_2O	*nitrous oxide*
nm	*nautical miles*
NO_X	*oxides of nitrogen*
OGV	*ocean-going vessel*
PM	*particulate matter*
PM_{10}	*particulate matter less than 10 microns in diameter*
$PM_{2.5}$	*particulate matter less than 2.5 microns in diameter*
PHA	*Port of Houston Authority*
ppm	*parts per million*
PTRA	*Port Terminal Railroad Association*
RoRo	*roll-on roll-off vessel*
rpm	*revolutions per minute*
S	*sulfur*
SO_X	*oxides of sulfur*
TCEQ	*Texas Commission on Environmental Quality*
TEU	*twenty-foot equivalent unit*
tonnes	*metric tons*
tpy	*tons per year*
U.S.	*United States*
ULSD	*ultra-low sulfur diesel*
USCG	*U.S Coast Guard*
VBP	*vessel boarding program*
VMT	*vehicle miles of travel*
VOC	*volatile organic compound*

SUMMARY OVERVIEW

SUMMARY OVERVIEW

PORT HOUSTON'S GOODS MOVEMENT EMISSIONS INVENTORY (GMEI)

Port Houston is committed to periodically conduct the GMEI assessment of Port-related emissions and the Clean Air Strategy Plan (CASP) to evaluate emissions from marine-related goods movement activities at Port Houston public terminals. This report estimates emissions from Port Houston marine facilities for 2023, compares them to 2019, and explains the changes in emissions. The activity-based inventory includes marine vessels, cargo handling equipment, heavy duty trucks and locomotive operations. Pollutants inventoried include relevant U.S. Environmental Protection Agency (EPA) criteria pollutants and precursors, including nitrogen oxides, sulfur dioxides, carbon monoxide, volatile organic compounds and particulate matter, as well as greenhouse gases (GHG).

MAJOR GROWTH ACCOMPANIED BY IMPROVED EFFICIENCY

The growth in cargo (tons) and containers moving through the Port was 16% and 28% respectively. The overall increase in GHG emissions (CO_2e) was 10% while NO_x and PM emissions are lower in 2023 as compared to 2019. The GHG emissions increase is lower than the cargo throughput increase. Despite the increase in cargo handling equipment emissions due to 280 additional pieces of cargo handling equipment in 2023, the overall NO_x and PM emissions are 7% and 4% lower, respectively. GHG emissions did not increase at the same rate as Port cargo growth indicating that the Port is continuing to reduce emissions per TEU..

	OCEAN-GOING VESSELS	HARBOR CRAFT	CARGO HANDLING EQUIPMENT	LOCOMOTIVE	HEAVY-DUTY TRUCKS	OVERALL TOTAL
NOx emissions	- 4% ↓	- 79% ↓	↑ 30%	- 7% ↓	- 2% ↓	- 7% ↓
PM2.5 emissions	- 3% ↓	- 78% ↓	↑ 36%	- 16% ↓	- 14% ↓	- 4% ↓
GHG emissions	- 3% ↓	- 70% ↓	↑ 47%	↑ 0.4%	↑ 30%	↑ 10%

TERMINAL EMISSIONS AT A GLANCE

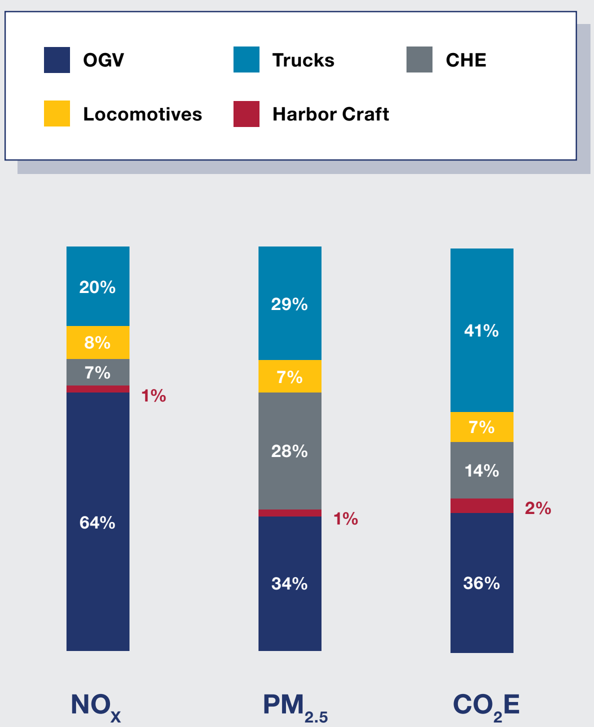
Bayport Container Terminal and Barbours Cut Container Terminal have the highest overall emissions followed by Turning Basin with the majority of cargo being breakbulk and project cargo terminal. The terminal emissions comparison includes at berth OGV emissions, CHE, harbor craft and on-terminal trucks. Barbours Cut and Turning Basin emissions are higher in 2023 than in 2019 due to cargo growth and additional equipment included. Bayport Container Terminal had lower NO_x and PM emissions in 2023 than 2019. Care Terminal and other facilities had lower emissions in 2023.

	BAYPORT TERMINAL	BARBOURS CUT TERMINAL	TURNING BASIN	CARE TERMINAL	OTHER FACILITIES
NO_x emissions	- 13%	4%	0%	- 19%	- 22%
PM2.5 emissions	- 2%	31%	60%	- 22%	- 12%
GHG emissions	13%	15%	3%	- 24%	- 11%

OCEAN-GOING VESSELS —

Largest contributor to Port Emissions, Decreased with Larger, Cleaner Vessels

Customer ocean-going vessels contribute the highest percentage of nitrogen oxides (NO_x) and particulate matter of 2.5 microns or less (PM2.5) emissions. Ocean-going vessels, both PHA and non-PHA, decreased in emissions due to fewer vessel movements in 2023. The reduction in vessel movements may be due to efficiency in loading/ unloading more cargo from fewer, larger vessels. In 2023, the number of Tier 3 vessels increased, and non-PHA alternative-fueled vessels numbered eight (8), with five (5) fueled by liquefied natural gas (LNG), and three (3) that used methanol. At PHA facilities, container ships (57%) and tankers (22%) had the highest percentage of NO_x emissions. For non-PHA facilities, tankers contributed 89% of NO_x emissions for OGV source category.



HEAVY-DUTY VEHICLES —

2nd Highest Emissions Reduced by Newer Trucks, Gate Improvements

Customer Heavy-Duty Vehicles (HDVs or trucks) are estimated to have the highest GHG emissions, shown as carbon dioxide equivalent (CO_2e) and the second highest emissions for NO_x and PM2.5. In 2023, NO_x and PM truck emissions are lower due to newer trucks with cleaner engines calling the PHA facilities. The higher CO_2e emissions for trucks are due to increased activity to move the increased cargo throughput. In 2023, 50% of the trucks that called PHA facilities had model year 2010 and newer, compared to 34% in 2019. The truck fleets are transitioning to newer trucks with cleaner engines. The 2010+ engines have significantly lower NO_x and PM emission rates due to the federal regulations with stricter engine standards.

Port Houston gate data tracks number of trucks, and trucks admitted to the Port are registered in the system, including their model years. Bayport Terminal saw 1.9 million truck visits in 2023, and Barbours Cut Terminal saw 1.3 million truck trips. Port Houston has extensively modernized gates to accommodate the increased cargo volume while minimizing truck idling times.

LOCOMOTIVES —

Emissions Decreased with Less Line Haul Activity

Locomotive emissions have a modest decrease between 2019 and 2023. The reductions in emissions are mainly due to lower locomotive engine standards for the current fleet. Locomotives are operated by the Port Terminal Rail Association, UP, BNSF, and KCS. In 2023, PTRA moved more than 500,000 railcars between terminals and interchange locations. Emissions-wise, rail is still one of the most efficient ways to move cargo.

CARGO HANDLING EQUIPMENT—

Record Growth Offset by Modest Emissions Increase

Emissions decreased in all transport/source categories except cargo handling equipment. To meet growth needs, the cargo handling equipment fleet has increased in count and used more in 2023. In 2023, new facilities and equipment operators were added to the inventory list which increased the equipment count by 17% from 2019 GMEI.

The Port had measures in place to reduce emissions impacts, including the purchase and conversion of RTG cranes to hybrid. A larger percentage of the newer equipment was used to move cargo. As a result of the hybrid equipment and newer equipment use overall, emission impacts were minimized throughout a period of significant growth at Port Houston.

Port Houston owns 17% of the 1,610 pieces of equipment on Port terminals. Port Houston owns and operates 123 CHE at Bayport, 135 at Barbours Cut, and 9 pieces at Turning Basin. The inventory includes 39 propane- or gasoline-fueled pieces of equipment, 31 hybrid RTGs, and 30 pieces of electric-powered equipment.

COMMERCIAL HARBOR VESSELS —

Lowest Emissions, Large Decrease, Cleaner Engines

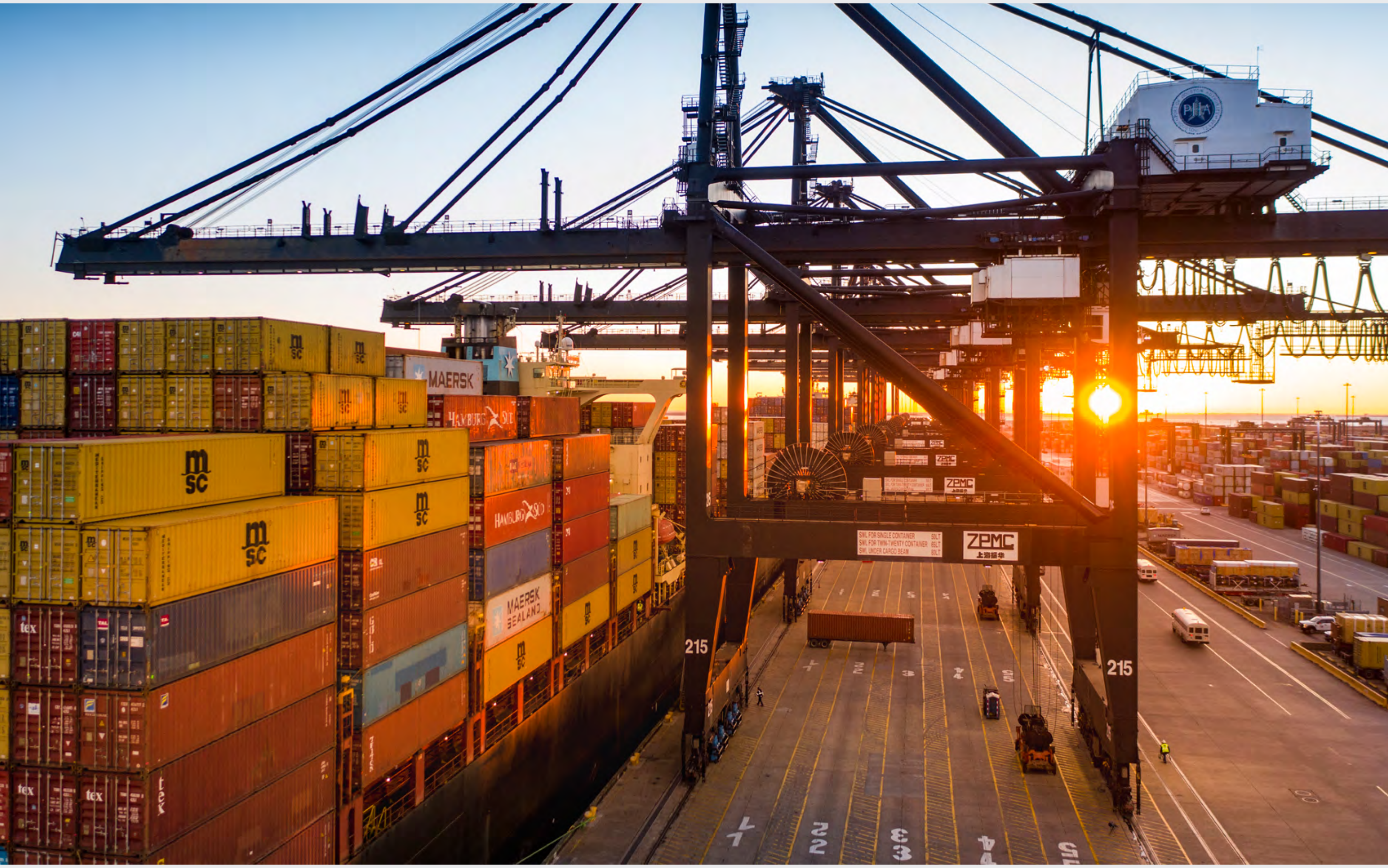
PHA commercial harbor vessels showed a significant decrease. In 2023, the number of Tier 0 engines has greatly decreased, at least for those vessels with known engine year. Although there was more vessel activity in 2023 than in 2019, the significant reduction is due to the transition to cleaner engines and less time spent in the area by the vessels. Harbor craft emissions not related to Port Houston showed a sharp increase for all pollutants due to the increase in tugboats and towboats in the HSC.

CONCLUSION —

Record Growth, Not Record Emissions!

Port Houston has successfully accommodated significant growth in business in the past several years by taking advantage of the resources at its disposal. Overall emissions have been reduced in the past 5 years as international, federal, state, regional, and Port Houston programs promote transport technologies that reduce the emissions. Equipment, locomotives, vehicles, and vessels are operating more efficiently. An increase in cleaner 2010+ trucks, newer equipment with Tier 3 and Tier 4 engines, hybrid and fully electric equipment, harbor vessels with newer engines, fewer vessel calls by larger vessels are all helping reduce overall emissions.

Still, the growth and increased activity indicates that CO_2e emissions may increase in the future as compared to 2023. Some of the emissions increases may be offset by fleet turnover as seen with this inventory. Since Port Houston is still expanding, future emissions inventory is recommended every three to five years. The ocean-going vessel inventory is especially crucial to understanding the changes in activity counts, vessel movements, alternative fuels used, and vessel types. Fleet turnover is occurring for commercial harbor craft, equipment and trucks. As the Port and marine terminal stevedores continue to replace equipment with newer engines and hybrid technologies, which will reduce mainly NO_x and PM emissions. The CO_2e emissions may increase with higher activity and fuel consumption.



SECTION ONE

INTRODUCTION

SECTION 1 Introduction

This section describes the rationale behind the 2023 Port Houston Goods Movement Emissions Inventory which includes maritime-related emissions associated with the eight public terminals owned and operated, or leased to others, by the Port of Houston Authority (PHA), also known as Port Houston. Port Houston is part of the Greater Port of Houston area which is a 25-mile-long complex of more than 200 private and public facilities centered along the 52-mile-long Houston Ship Channel. The Greater Port of Houston area (private and public facilities) achieved the number one ranking in total waterborne tonnage in the United States (U.S.) in 2023 and the largest Texas port by tonnage. The port complex is located within the Houston-Galveston-Brazoria (HGB) ozone nonattainment area, which consists of the eight Texas counties of Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties.

1.1 REASON FOR STUDY

Port Houston undertook this study to estimate maritime-related mobile source emissions that occurred in 2023 for the public terminals, and to compare those emissions to the 2019 Goods Movement Emissions Inventory. An emissions inventory is a very useful tool to quantify mass emissions and track emission changes over time from a variety of emission sources in a geographic area and to help prioritize those sources for potential emission reduction measures. The high-level comparison of 2023 emissions with 2019 emissions, detailed in Section 8, will assist the Port staff in understanding how the Port's continued growth and emission reduction strategies have affected maritime-related emissions and their relationship to emissions in the area as a whole.

The Houston Ship Channel and greater Houston area have experienced some of the highest growth rates in the country in recent years, both economically and by regional population. Energy production, the petrochemical industry, and growth in trade due to the 2015 repeal of crude oil export ban and higher U.S. consumerism have helped drive economic prosperity in the region.

The maritime-related emissions should be viewed in the context of being a part of the region's total air emissions. Other (non-maritime) categories that contribute to area emissions include point sources (refineries, manufacturing facilities, etc.); on-road mobile sources (e.g., cars, trucks, buses and motorcycles); non-road equipment (farming equipment, construction equipment, etc.); and area sources (open burning, auto body shops, etc.). To provide context, maritime-related emissions are compared to the regional emissions (see Section 2.3).

1.2 SCOPE OF STUDY

The scope of the study is described in terms of the pollutants quantified, the year of operation used as the basis of emission estimates, the emission source categories that are included and excluded, and the geographical extent of activities included in the inventory.

1.2.1 POLLUTANTS

Exhaust emissions of the following pollutants are estimated:

- Criteria pollutants, surrogates, and precursors – reported in short tons (tons)
  - Oxides of nitrogen (NO_X)
  - Sulfur dioxide (SO_2)
  - Particulate matter (PM) (10-micron, 2.5-micron)
  - Volatile organic compounds (VOCs)
  - Carbon monoxide (CO)
- Greenhouse gases (GHGs) – reported as CO_2 equivalent (CO_2e in metric tons (tonnes)
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous oxide (N_2O)

Most maritime-related sources of GHG emissions involve fuel combustion, thus the combustion-related emissions of CO_2, CH_4, and N_2O are included in this inventory. Because each greenhouse gas differs in its effect on the atmosphere, estimates of greenhouse gas emissions are presented in units of carbon dioxide equivalents, which weight each gas by its global warming potential (GWP) value. To normalize these values into a single greenhouse gas value, CO_2e, the GHG emission estimates are multiplied by the following GWP values[1] and summed: 1 for CO_2, 28 for CH_4 and 265 for N_2O. The resulting CO_2e emissions are presented in tonnes (metric tons) throughout the report, whereas all other annual emissions are presented as tons (short tons).

1.2.2 TEMPORAL EXTENT

The activity year for this study is calendar year 2023. To the extent practicable, the emission estimates are based on activities that occurred during this period. If information specific to 2023 was not available, reasonable estimates of operational characteristics were developed. These cases are identified in the text for each source category.

1.2.3 EMISSION SOURCE CATEGORIES

This study includes the following emission source categories:

- Ocean-going vessels
- Commercial harbor craft
- Cargo handling equipment
- Locomotives
- Heavy-duty vehicles

1 EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, April 2024.

1.3 GEOGRAPHICAL DOMAIN

The following PHA facilities located in Harris County and shown in Figure 1.1 are included for all emission source categories:

- Bayport Container Terminal
- Barbours Cut Container Terminal
- Jacintoport Terminal
- Care Terminal
- Bulk Materials Handling Plant
- Woodhouse Terminal
- Sims Bayou
- Old Manchester Terminal
- Southside Wharves
- Industrial Park East
- Turning Basin Terminal

Figure 1.1: PHA Facilities

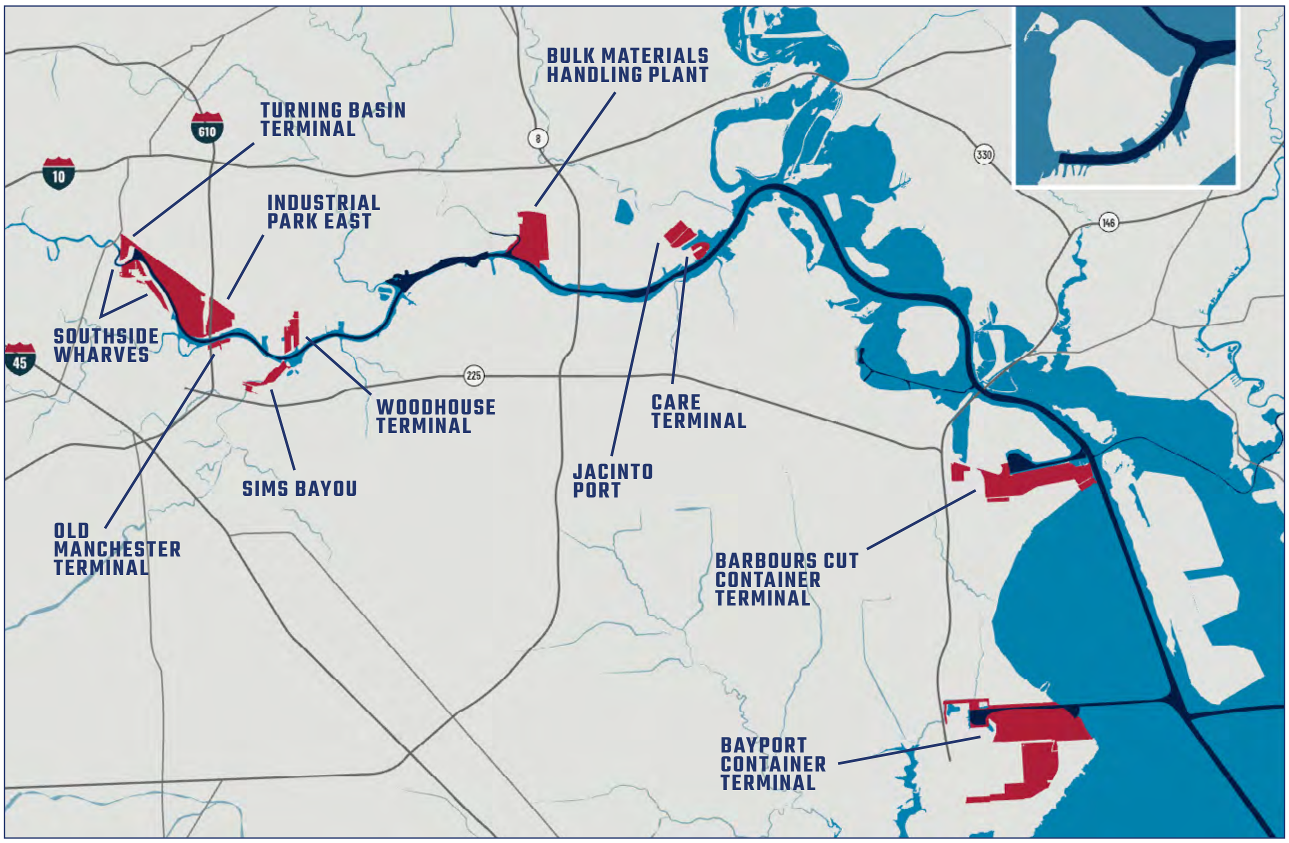


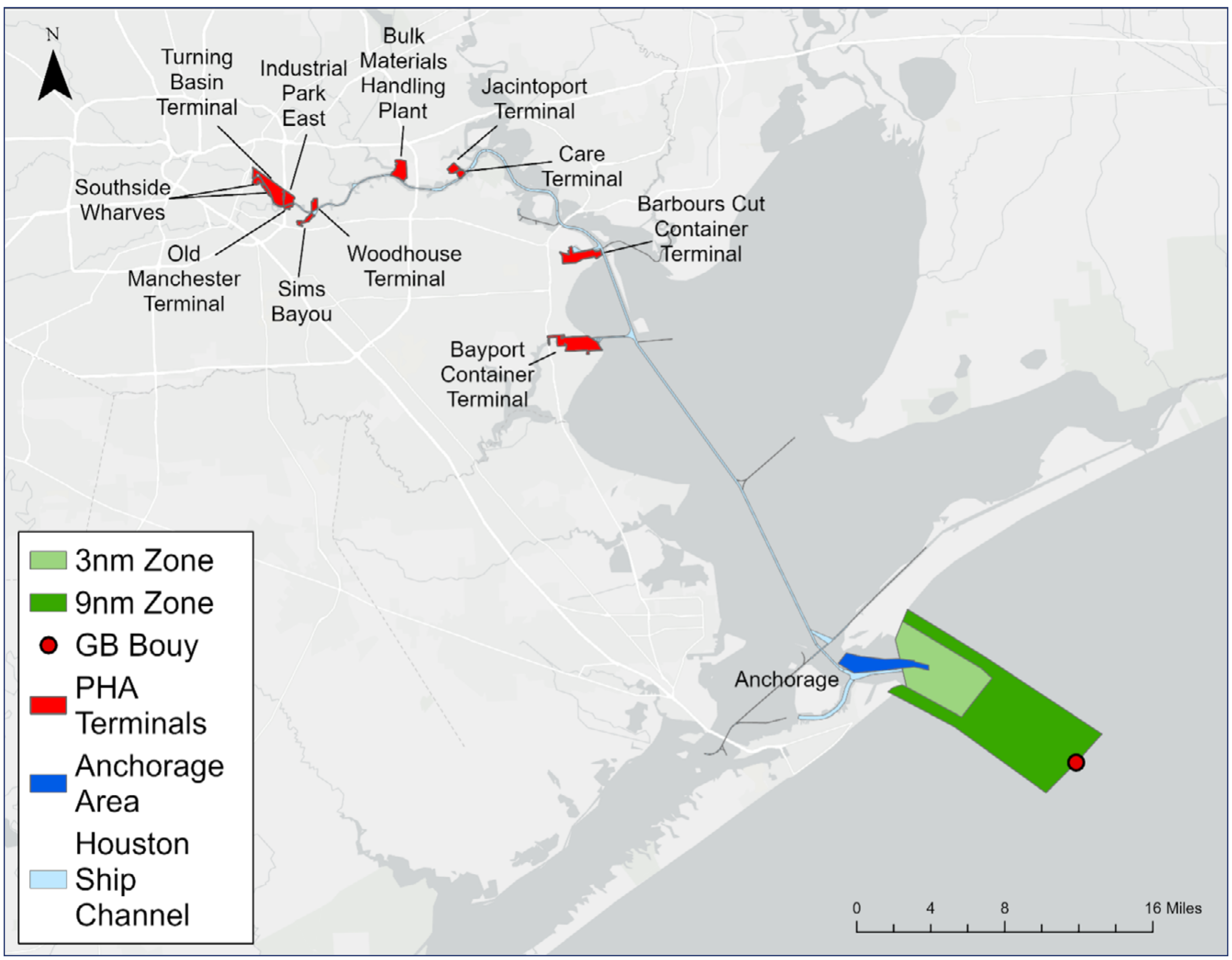
Figure 1.2: Aerial Photos of the Houston Ship Channel

The 2023 GMEI includes the following geographical domains for each source category:

- Ocean-going vessels (OGV) – activity associated with PHA properties and the Houston Ship Channel.
- Harbor vessels - activity associated with PHA properties and the Houston Ship Channel.
- Cargo-handling Equipment (CHE) – activity on PHA properties.
- Railroad activity – yard and line haul operations associated with PHA freight movements within the HGB non-attainment area.
- On-road heavy-duty vehicles (HDV) – drayage and other goods movement operations for heavy-duty trucks that visit the PHA terminals and occur within the HGB non-attainment area.

The marine vessel geographical domain includes the extent of the Port of Houston Authority, in addition to the numerous private industrial companies along the Houston Ship Channel, and the maneuvering and transiting zones extend nine nautical miles (nm) off the coast at the outer sea buoy (Galveston Bay entrance channel GB bouy). Figure 1.3 illustrates the geographic domain for commercial marine vessels including ocean-going vessels and harbor vessels such as towboats/pushboats.

Figure 1.3: Marine Vessels Geographical Domain



SECTION TWO

SUMMARY RESULTS & COMPARISON

SECTION 2 Summary Results & Comparison

The emissions in this section are separated into two sections: PHA emissions for public terminals for five source categories and non-PHA emissions which include OGV and commercial harbor vessel emissions for the private facilities.

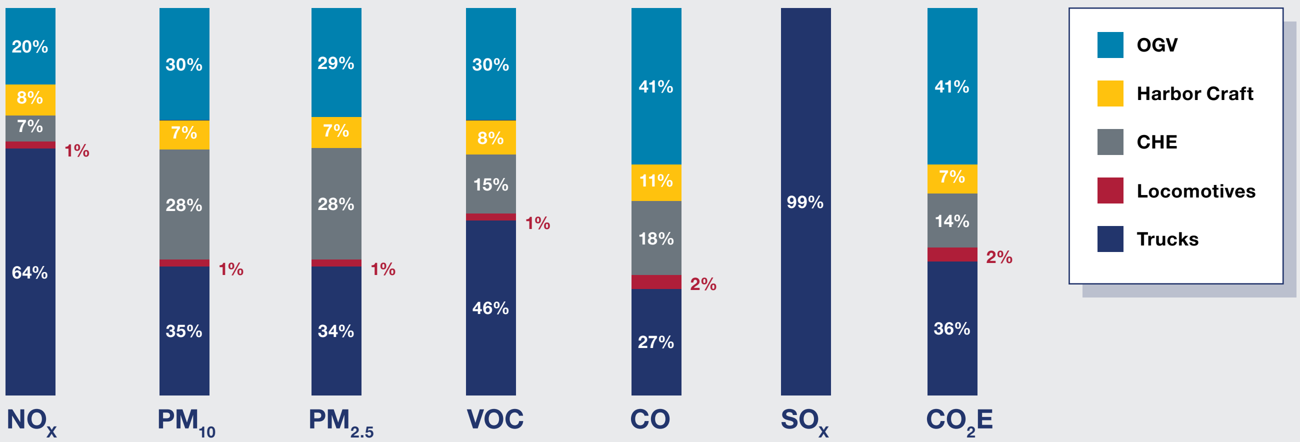
2.1 PHA EMISSIONS

The 2023 emissions from maritime-related mobile sources associated with PHA are summarized in Table 2.1. As discussed in Section 1, the CO_2e emissions are presented in tonnes rather than short tons and have been calculated using the GWP values listed in Section 1. Figure 2.1 illustrates the distribution of PHA NO_x emissions by source category for activity associated with PHA properties only.

Table 2.1: 2023 PHA-Only Maritime-related Emissions

	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2E
	tons						tonnes
Ocean-going vessels	4,536	70	65	143	365	178	268,613
Commerical harbor vessels	103	3	3	3	32	0.1	12,136
Cargo handling equipment	475	56	53	48	248	0.4	105,993
Locomotives	548	14	13	26	154	0.6	53,525
Heavy-duty vehicles	1,372	60	55	93	548	1.1	304,519
Total	**7,034**	**202**	**188**	**313**	**1,348**	**180**	**744,786**

Figure 2.1: 2023 PHA-Only Distribution of Emissions by Source Category, %



Between 2019 and 2023, PHA saw significant growth in cargo volume and moved up in port size rankings. During that period expansion projects were completed at Bayport and Barbour's Cut Terminals, and new terminals commenced operations, such as a cement import terminal. Cargo throughput, measured in tons, increased 16% while the container throughput, measured in TEU, increased 28% in 2023 as compared to 2019.

Table 2.2: 2023 vs 2019 PHA-associated Cargo Volume Comparison[2]

YEAR	CARGO (short tons)	CONTAINERS TEU
2023	50,323,264	3,826,157
2019	43,235,690	2,990,175
Change (%)	**16%**	**28%**

The 2023 vs 2019 PHA emissions comparison is summarized in Table 2.3. The NO_x, PM, VOC, and SO_x emissions are lower in 2023 compared to 2019. The emission reductions despite the double-digit cargo and container growth are commendable. It shows that Port Houston and its facilities, customer fleets and stevedores have implemented strategies to reduce emissions.

Table 2.3: 2023 vs 2019 PHA Emissions Comparison

	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
2023							
Ocean-going vessels	4,536	70	65	143	365	178	268,613
Commerical harbor vessels	103	3	3	3	32	0.1	12,136
Cargo handling equipment	475	56	53	48	248	0.4	105,993
Locomotives	548	14	13	26	154	0.6	53,525
Heavy-duty vehicles	1,372	60	55	93	548	1.1	304,519
Total	**7,034**	**202**	**188**	**313**	**1,348**	**180**	**744,786**
2019							
Ocean-going vessels	4,730	72	67	148	370	183	276,730
Commerical harbor vessels	496	12	12	12	113	0.4	39,805
Cargo handling equipment	365	41	39	36	138	0.3	72,159
Locomotives	587	16	16	27	153	0.6	53,329
Heavy-duty vehicles	1,395	70	64	96	498	0.9	233,748
Total	**7,573**	**211**	**197**	**319**	**1,272**	**185**	**675,771**
Change between 2023 and 2019 (percent)							
Ocean-going vessels	-4%	-3%	-3%	-4%	-1%	-3%	-3%
Commerical harbor craft	-79%	-78%	-78%	-77%	-72%	-69%	-70%
Cargo handling equipment	30%	36%	36%	31%	79%	42%	47%
Locomotives	-7%	-14%	-16%	-2%	1%	-1%	0%
Heavy-duty vehicles	-2%	-14%	-14%	-3%	10%	25%	30%
Total	**-7%**	**-4%**	**-4%**	**-2%**	**6%**	**-3%**	**10%**

2 Data source: Port of Houston Authority Monthly Cargo Statistical Summary December 2024 for 2023 TEU and Annual Summary of Port Houston Cargo Tonnage Statistics for 2023, https://porthouston.com/about/our-port/statistics/

Please note the 2019 OGV emissions were re-estimated for improved methodology with speeds and distances when working with AIS data, therefore the 2019 total emissions shown here do not match the emissions listed in the prior 2019 GMEI. The 2019 CHE emissions were re-estimated also using the latest methodology.

Major highlights for PHA that impacted PHA emissions in 2023 as compared to 2019:

- The overall vessel movements decreased 5% for PHA terminals in 2023 as compared to 2019, despite an increase in TEU throughput and containership calls. The reduced number of total vessel calls resulted in lower OGV emissions.In 2023, there were eight alternative fueled vessels; 5 that used LNG and 3 that used methanol.
- In 2023, there were 33 vessels with Tier III propulsion engines that called PHA terminals. In 2019, there were only four vessels. NO_x emissions from Tier III vessels are 75% lower than from Tier II vessels when operating at or above 25% main engine load.
- PHA's commitment to hybrid cranes. In 2023, there were 31 hybrid RTG cranes as compared to 5 in 2019.
- Increased use of newer equipment. In 2023, 72% of the energy consumed by CHE were from cleaner engines as compared to 65% in 2019.
- Equipment and vehicle turnover to newer equipment/vehicles with cleaner engines. In 2023, 50% of the truck trips were made by 2010+ model year trucks which have the cleanest NO_x and PM engine standards. This is an improvement from 2019 which had 34% with 2010+ trucks.

Table 2.4 summarizes the emissions by the top four terminals (Bayport, Barbours Cut, Turning Basin and Care) with the other PHA terminals combined. Locomotive emissions are not included in this terminal table because they cannot be easily separated by terminal since locomotives handle cargo for all facilities in the area and do not have rail activity separated by terminal. The total will not match the 2023 emissions as it excludes locomotive emissions. The terminal emissions include emissions that occur within the study area, therefore it includes OGV at berth and while transiting; trucks on terminal and traveling on regional roads, cargo handling equipment and harbor craft emissions associated with PHA terminals. The two container terminals, Bayport Terminal and Barbours Cut Terminal, have the highest emissions and account for over 50% of the PHA emissions by terminal as listed on Table 2.4.

Table 2.4: 2023 PHA Emissions by Terminal excluding Locomotive Emissions

TERMINAL	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2E
	tons						tonnes
Bayport Terminal	2,643	69	64	112	463	69	304,320
Barbours Cut Terminal	1,916	59	55	85	333	48	197,482
Turning Basin	880	34	32	48	180	22	93,434
Care Terminal	217	6	5	7	24	11	19,280
Other Terminals	831	21	19	34	192	29	76,745
Total	**6,486**	**188**	**175**	**287**	**1,193**	**179**	**691,261**

2.2 NON-PHA EMISSIONS

In addition to the emissions associated with PHA terminals, emissions were also estimated for ocean- going vessels and commercial harbor vessels that transited through the Houston Ship Channel and/or called on private facilities that are not related to PHA. The non-PHA emissions are listed in Table 2.5.

Table 2.5: 2023 Non-PHA Emissions

	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Ocean-going vessels	7,211	166	152	240	706	431	651,974
Commerical harbor vessels	5,136	116	112	150	1,112	5	468,522
Total	**12,347**	**281**	**265**	**390**	**1,818**	**436**	**1,120,496**

The 2023 and 2019 OGV and commercial harbor vessels emissions for non-PHA entities in the Houston Ship Channel are included in Table 2.6. The emissions for private entities (non-PHA) increased across the board in 2023 due to increased continued demand for liquid bulk exports which increased towboats and tugboats associated with liquid bulk barges. For non-PHA OGV emissions, the decrease in emissions is due to fewer vessel movements in 2023 which may be due to efficiency in loading/unloading more cargo with fewer vessel movements. The harbor craft emissions are higher for all pollutants due to more tugboats and towboats in the Houston Ship Channel.

Table 2.6: 2023 vs 2019 Non-PHA Emissions by Source Category

	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
2023							
Ocean-going vessels	7,211	166	152	240	706	431	651,974
Commerical harbor vessels	5,136	116	112	150	1,112	5	468,522
Total	**12,347**	**281**	**265**	**390**	**1,818**	**436**	**1,120,496**
2019							
Ocean-going vessels	8,209	175	161	253	726	455	688,351
Commerical harbor vessels	3,816	88	85	93	847	3	302,443
Total	**12,025**	**263**	**246**	**346**	**1,573**	**458**	**990,794**
Change between 2023 and 2019 (percent)							
Ocean-going vessels	-12%	-5%	-5%	-5%	-3%	-5%	-5%
Commerical harbor craft	35%	31%	31%	62%	31%	55%	55%
Total	**3%**	**7%**	**7%**	**13%**	**16%**	**-5%**	**13%**

The following activity impacted the private facilities (non-PHA) emissions in 2023:

- The Houston Ship Channel (HSC) is being widened by 170 feet in a phased approach. Dredging began in 2022 to also deepen the channel which will result in larger vessels and less waiting time. The project is expected to be completed in 2029, so the 2023 vessel activity was impacted slightly by this project on segments completed.
- In 2023, there were 317 vessels with Tier III propulsion engines that called non-PHA entities, including 309 tankers, one general cargo vessel and one bulk vessel. This was a tenfold increase in vessel counts with Tier III engines from 2019 and a reason for the vessel's lower NO_x emissions in 2023. NO_x emissions from Tier III vessels are 75% lower than from Tier II vessels when operating at or above 25% main engine load.

- In 2023, there were eight alternative fueled vessels; 5 that used LNG and 3 that used methanol.
- For commercial harbor craft, the emissions increased for all pollutants due to increased workboat and towboat activity. The articulated tug barge (ATB) activity is included mainly in the harbor craft activity for 2023 which increased the harbor craft vessel count and activity. In 2019, the ATB activity was included with OGVs as opposed to harbor craft. Tugboat/towboat movements increased in 2023 due to the continued demand for liquid bulk exports.

2.3 COMPARISON TO REGIONAL EMISSIONS

Part of the scope of this study was to obtain and summarize the regional emissions inventory categories for air quality planning purposes. The emission estimates for the HGB region were compiled from 2023 emissions data provided by TCEQ for point source, area source, on-road and non-road mobile compiled from various data sources. Table 2.7 compares 2023 PHA emissions to the 2023 eight county regional emissions for Houston Galveston Brazoria (HGB) area.

Table 2.7: PHA Emissions Comparison to HGB Regional Emissions, tpy

	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x
	tons					
2023 PHA	7,034	202	188	313	1,348	180
2023 8-County HGB	111,687	124,674	29,791	157,661	496,567	39,185
Percent of PHA-related	**6.3%**	**0.2%**	**0.6%**	**0.2%**	**0.3%**	**0.5%**
2019	**6.3%**	**0.2%**	**0.6%**	**0.2%**	**0.3%**	**0.4%**

The PHA-related NO_x emissions contribution (6.3%) and $PM_{2.5}$ emissions contribution (0.6%) for the region remained the same in 2023 as compared to 2019 contribution. Figures 2.2 and 2.3 show PHA's NO_x and $PM_{2.5}$ contribution to the HGB region.

Figure 2.2: 2023 PHA NO_x Emissions Contribution the HGB Regional Emissions

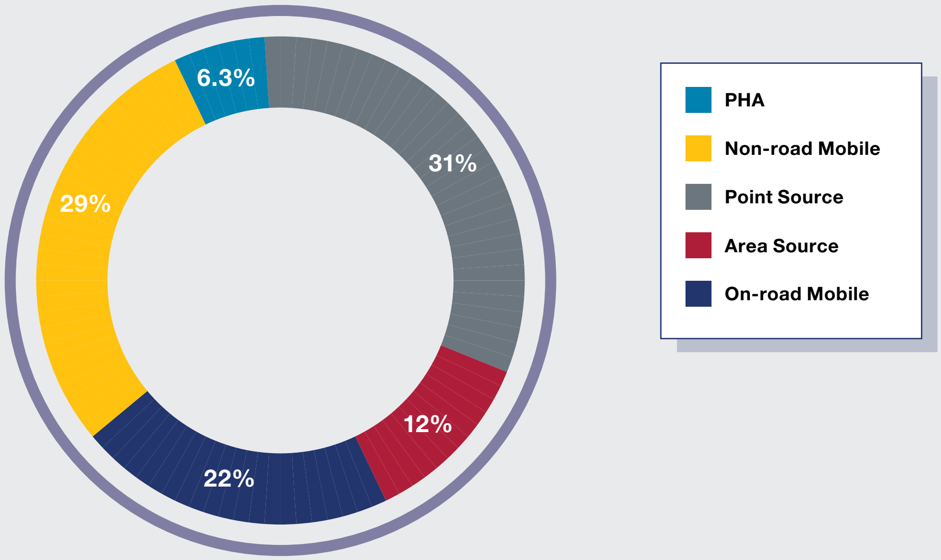


Figure 2.3: 2023 PHA $PM_{2.5}$ Emissions Contribution the HGB Regional Emissions

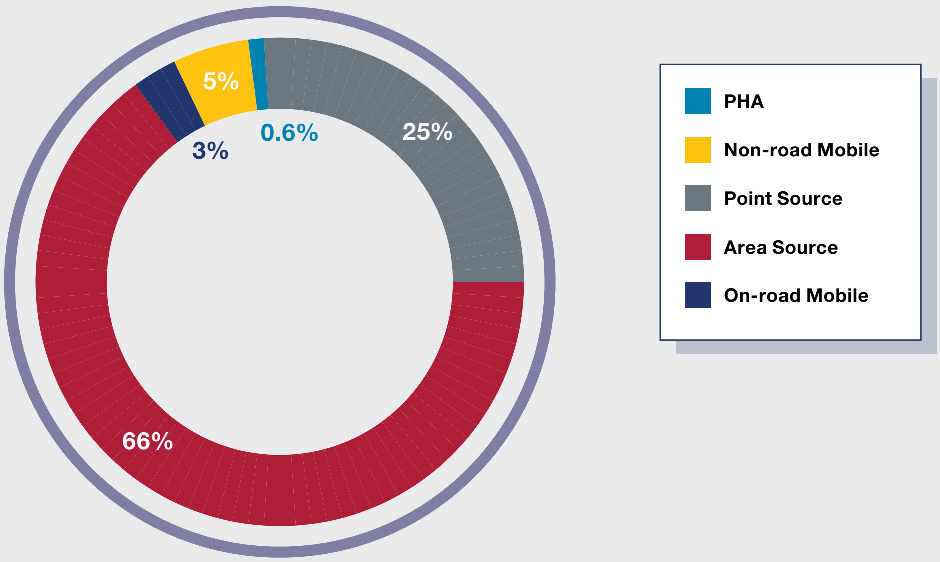


Table 2.8 summarizes the contribution of PHA NO_x emissions by source category to the regional emissions provided by TCEQ for the eight-county HGB area in 2023 and 2019. The Counties included in TECQ's regional emissions are Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller. Only cargo handling equipment have a slightly higher NO_x contributions in 2023 than in 2019.

Table 2.8: 2023 vs 2019 Comparison of PHA NO_x Contribution to HGB Regional Emissions

YEAR	2023 NO_x %	2019 NO_x %
OGV & Harbor Craft	4.2%	4.2%
CHE	0.4%	0.3%
Locomotive	0.5%	0.5%
Heavy-duty vehicles	1.2%	1.3%
PHA	**6.3%**	**6.3%**

SECTION THREE

OCEAN-GOING VESSELS

SECTION 3 Ocean-Going Vessels

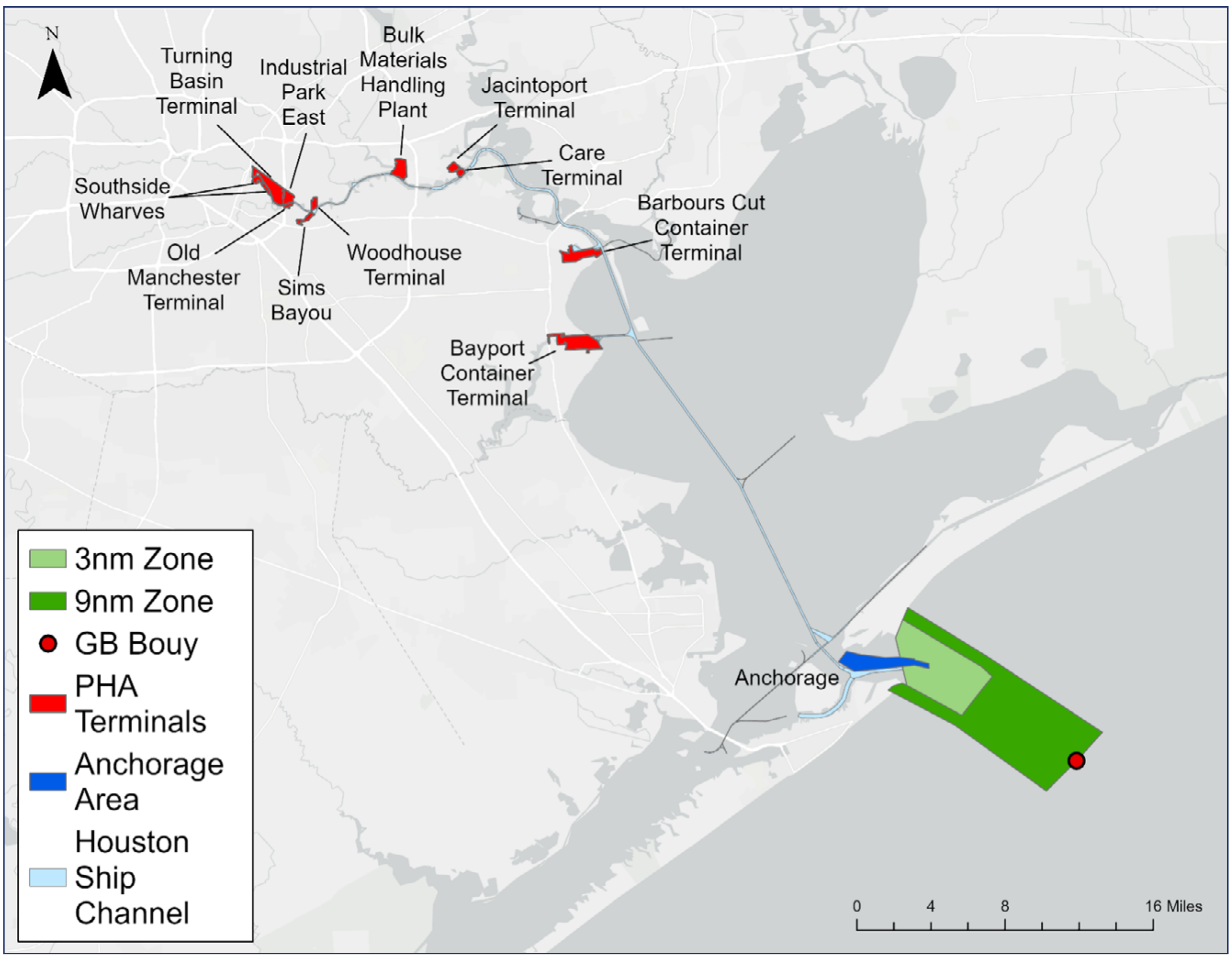
This section presents emissions estimates for the ocean-going vessels (OGV or vessels) source category. It is organized into the following subsections: source description (3.1), data and information acquisition (3.2), operational profiles (3.3), emissions estimation methodology (3.4), and OGV emission estimates (3.5).

3.1 SOURCE DESCRIPTION

The OGV activity and emissions included in this section include 1) activity directly associated with PHA properties and 2) activity for the Houston Ship Channel that is not PHA-associated (non-PHA). The Bolivar anchorage area activity is included, with anchorage hoteling emissions apportioned between PHA and non-PHA depending on whether the vessel ultimately called a PHA facility or not.

The geographical domain includes the Houston Ship Channel, Galveston Bay, Trinity Bay, and Bolivar anchorage area and extends nine nautical miles (nm) from shore to the GB Buoy. Figure 3.1 illustrates the outer limit of the geographic domain on the ocean side for commercial marine vessels.

Figure 3.1: Geographic Domain



The following vessel types called the PHA terminals in 2023:

- **Auto carrier** – *vehicle carriers that can accommodate vehicles and large wheeled equipment.*
- **Bulk carrier** – *vessels with open holds to carry various bulk dry goods, such as grain, salt, sugar, petroleum coke, and other fine-grained commodities.*
- **Containership** – *vessels that carry standardized intermodal shipping containers on their decks and in their holds, and transport primarily retail goods.*
- **General cargo** – *vessels that are designed to carry a diverse range of cargo in their hold and on their decks, such as bulk metals, machinery, and palletized goods.*
- **Roll-on roll-off vessel** (RoRo) – *commonly known as RoRos, these vessels can accommodate vehicles and large wheeled equipment.*
- **Tanker** – *vessels that transport liquids in bulk, such as oil, chemicals, or other specialty goods such as molasses or asphalt. Tankers are classified based on their size.*

Figure 3.2: Photo of Containership

Figure 3.3: Photo of General Cargo Vessel

Figure 3.4: Photo of Tanker

Table 3.1 presents the number of arrivals, departures, and shifts for the vessels that called PHA terminals only in 2023 with an overall comparison to 2019. A shift is a vessel movement of a vessel from one berth to another within the port complex.

Table 3.1: PHA Arrivals, Departures, and Shifts by Vessel Type

Vessel Type	Arrivals	Departures	Shifts	Totals
Auto Carrier	64	65	1	130
Bulk	352	356	93	801
Containership	1,036	1,032	13	2,081
General Cargo	218	216	45	479
RoRo	10	10	0	20
Tanker	662	498	611	1,771
Total	**2,342**	**2,177**	**763**	**5,282**
2019	**2,500**	**2,311**	**748**	**5,559**
2023 vs 2019	**-6%**	**-6%**	**2%**	**-5%**

Table 3.2 presents the number of arrivals, departures, and shifts for vessels that called the private facilities in the Houston Ship Channel (Non-PHA) terminals only in 2023 with an overall comparison to 2019. It shows less overall vessel calls in 2023 as compared to 2019. The table includes 2019 counts for arrivals, departures and shifts for comparison.

Table 3.2: Non-PHA Arrivals, Departures, and Shifts by Vessel Type

Vessel Type	Arrivals	Departures	Shifts	Totals
Auto Carrier	4	3	19	26
Bulk	277	283	110	670
Containership	0	1	2	3
General Cargo	324	328	110	762
ATB	5	5	2	12
Tanker	4,082	4,241	2,756	11,079
Total	**4,692**	**4,861**	**2,999**	**12,552**
2019	**4,884**	**5,011**	**3,479**	**13,374**
2023 vs 2019	**-4%**	**-3%**	**-14%**	**-6%**

Figures 3.5 and 3.6 show the percentage of calls by vessel type for PHA terminals and for the Houston Ship Channel (non-PHA), respectively, based on arrivals. The vessels that call PHA terminals consist of containerships (44%) followed by tankers (28%), with the balance being various other vessel types. The vessels that call non-PHA terminals are predominantly tankers (88%).

Figure 3.5: 2023 PHA Distribution of Calls by Vessel Type

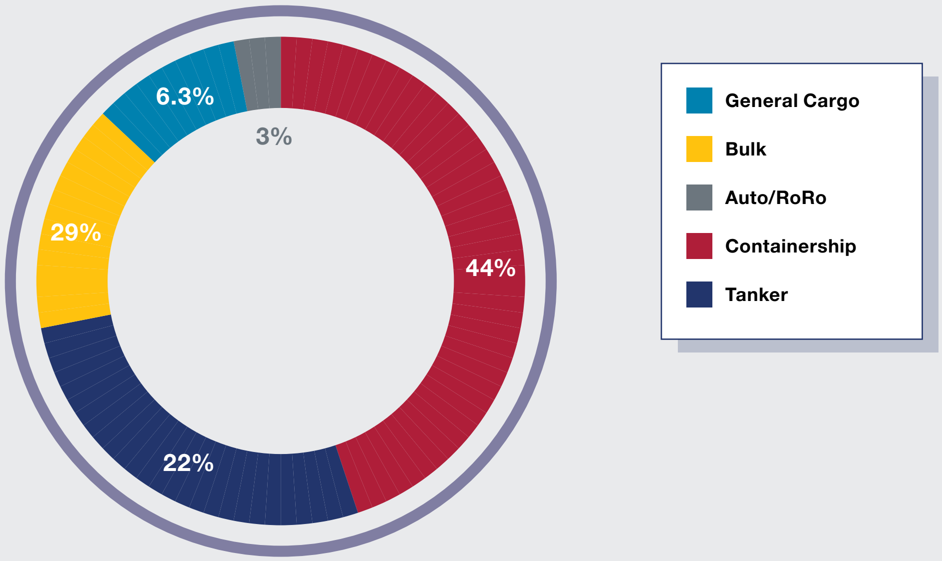
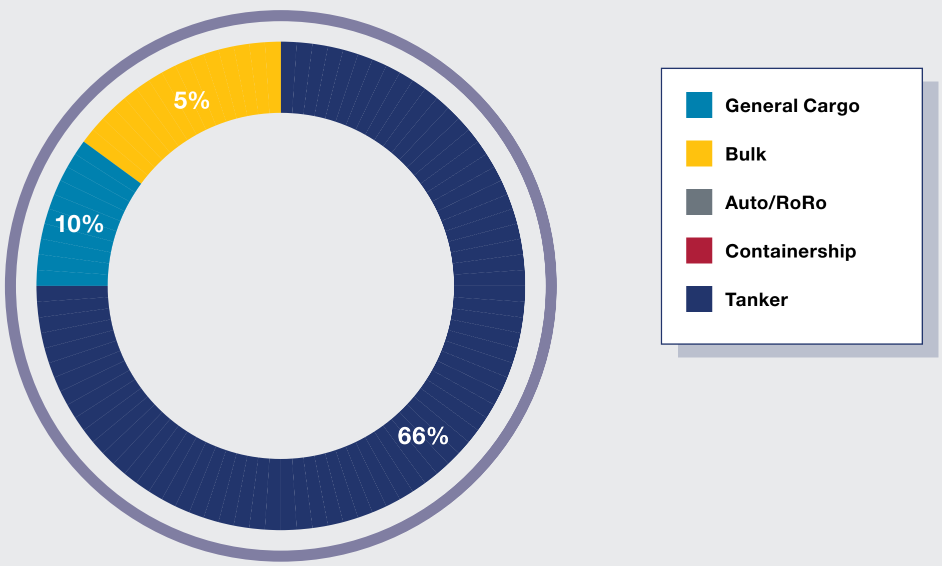


Figure 3.6: 2023 Houston Ship Channel (Non-PHA) Distribution of Calls by Vessel Type



3.2 DATA AND INFORMATION ACQUISITION

The OGV emission estimates presented in this report are primarily based on actual vessel activity data for those vessels that visited in 2023, vessel operational data, and vessel parameter data. Activity of each vessel was determined from automatic information system (AIS) data. The AIS data was used for identifying vessels operating within the geographical domain and processed to determine discrete vessel activity parameters including speed over water and time in mode. This data was collected through the AIS receiver network administered by the U.S. Coast Guard (USCG) and compiled into files comprised of unique AIS records. AIS data points contain vessel specific geographical and temporal information including but not limited to: International Maritime Organization (IMO) number, maritime mobile service identity (MMSI) number, geographic coordinates, speed over water, heading, date, and time. The AIS data was processed into vessel call activity through a combination of database processing and Geographic Information System (GIS) analysis. The processed AIS data provides vessel specific speed profiles and time spent operating in the approach and maneuvering zones, as well as hotelling time at a PHA terminal. Table 3.3 summarizes the hotelling times at berth for vessels that called PHA terminals.

Table 3.3: PHA Hotelling Times at Berth, hours

Vessel Type	MIN Hrs	MAX Hrs	AVG Hrs
Auto Carrier	7	59	22
Bulk	6	2,969	123
Bulk - Heavy Load	211	211	211
Container 1000	7	380	31
Container 2000	9	121	30
Container 3000	8	45	24
Container 4000	17	85	41
Container 5000	5	103	39
Container 6000	7	97	44
Container 7000	30	91	58
Container 8000	2	94	52
Container 9000	26	99	56
Container 10000	46	46	46
General Cargo	6	619	94
RoRo	51	114	75
Tanker - Chemical	4	250	45
Tanker - LPG	25	71	45
Tanker - Handysize	9	105	48
Tanker - Panamax	12	64	25
Tanker - Aframax	19	214	90

The actual time at berth for each vessel is used to estimate emissions. Times presented in Table 3.3 only show minimum, maximum and average. Each year, there may be one or two outliers in the data that show vessels staying longer than normal due to maintenance or other issues.

Starcrest has an ongoing Vessel Boarding Program (VBP) to collect data from ships engineers at various ports to determine auxiliary engine and boiler loads during various vessel operation modes. This effort was initiated as there is no publicly available data source for this type of vessel operation. When available, vessel operational data from VBP is used. If VBP data was not available, averages of VBP data by vessel type as defaults are being used. The vessel specific parameters include vessel type, engine type, propulsion engine horsepower, maximum rated speed of propulsion engine, keel laid date, and other parameters are obtained from S&P Global (formerly IHS Markit) dataset[3].

In 2023, there were a total of 348 vessels with Tier III propulsion engines that called PHA and non-PHA entities as compared to 37 Tier III vessels in 2019. The 2023 Tier III vessel types are:

- 309 tankers, 7 bulk vessels and 1 general cargo vessel called non-PHA terminals.
- 15 tankers, 14 bulk vessels, 2 containerships and 2 general cargo vessels called PHA terminals.

NO_x emissions for Tier III vessels are 75% cleaner than Tier II vessels when operating above 25% main engine load. Table 3.4 presents the percent propulsion engine Tier by vessel type for PHA vessel calls. It shows that most of the vessels have Tier I and II engines. In 2023, 3% of the propulsion engines are Tier III.

Table 3.4: PHA OGV Propulsion Engine Tier by Vessel Type, %

Vessel Type	Tier 0	Tier 1	Tier 2	Tier 3
Auto Carrier/ RoRo	0%	58%	42%	0%
Bulk	1%	33%	63%	4%
Containership	4%	82%	13%	1%
General Cargo	9%	73%	18%	1%
Tanker	7%	40%	45%	8%
2023 Tier Percent	**4%**	**55%**	**37%**	**3%**
2019 Tier Percent	**6%**	**56%**	**37%**	**1%**

3 https://www.spglobal.com/en

3.3 OPERATIONAL PROFILES

Emission estimates have been developed for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers.

Fuel sulfur content plays an important role in marine vessel emissions. The emission estimates are calculated based on the assumption that vessels were operated using marine diesel fuel with an average sulfur content (S) of 0.1% per IMO's requirement for the North American ECA. Several vessels are identified to use LNG or methanol fuel in non-PHA EI geographical domain. Based on the geographical domain and operational information, the following vessel operational modes define the characteristics of a vessel's operation within the emission inventory domain:

1. **Transit at slower speeds** - *Vessel movements inside the EI geographical boundary, after the vessel enters the EI geographic domain (arrival) or before the vessel departs the EI geographical boundary (departure). Additional power is typically brought online as a safety measure since the vessel is preparing to travel to or is traveling in restricted waters. Propulsion engines, auxiliary engines and boilers are in operation during maneuvering.*
2. **At-Berth** - *When a ship is stationary at the dock/berth/anchorage. Auxiliary engines and boilers are in operation while the vessel is at-berth.*
3. **Shift** - *When a ship moves from one berth to another within the EI geographical boundary. Propulsion engines, auxiliary engines and boilers are in operation during maneuvering.*

3.4 EMISSION ESTIMATION METHODOLOGY

In general, emissions are estimated as a function of vessel engines/boilers energy demand expressed in kW-hr multiplied by an emission factor, where the emission factor is expressed in terms of grams per kilowatt-hour (g/kW-hr). Emission factor adjustments for different propulsion engine loads (see section 3.4.4), or emissions controls are also accounted when estimating OGV emissions.

Equations 3.1 and 3.2 are the basic equations used in estimating emissions by mode.

$$Ei = Energy_i \times EF \times FCF \times CF \qquad \textbf{EQUATION 3.1}$$

WHERE:

E_i = Emissions by mode

$Energy_i$ = Energy demand by mode, calculated using Equation 3.2 below as the energy output of the engine(s) or boiler(s) over the period of time, kW-hr

EF = Emission Factor, expressed in terms of g/kW-hr. Emission factors are based on type of the fuel and engine type.

FCF = Fuel Correction Factor(s) are used in the equation if the fuel used to develop the EF is different than the actual fuel used, dimensionless. For 2023 EI, FCF are not used.

CF = Control Factor(s) are used to adjust baseline emissions for emission reduction technologies, dimensionless, for 2023 EI, CFs are not used.

The 'Energy' term of the equation is where most of the location-specific information is used. Energy by mode is calculated using Equation 3.2:

EQUATION 3.2

$$Energy_i = Load \times Act$$

WHERE:

Energy$_i$ = Energy demand by mode, kW-hr

Load = maximum continuous rated Power (MCR) times load factor (LF) for propulsion engine power (kW); reported operational load of the auxiliary engine(s), by mode (kW); or reported operational load of the auxiliary boiler, by mode (kW)

Act = activity, hours

The emissions estimation methodology for propulsion engines can be found in subsections 3.4.1 to 3.4.5, for auxiliary engines subsections 3.4.6, and for auxiliary boilers subsection 3.4.7. Propulsion engines are also referred to as main engines. Incinerators are not included in the emissions estimates because interviews with the vessel operators and marine industry indicate that vessels do not use their incinerators while at-berth or near coastal waters.

3.4.1 PROPULSION ENGINE MAXIMUM CONTINUOUS RATED POWER (MCR)

MCR power is defined as the manufacturer's tested maximum engine power and is used to determine propulsion engine load by mode. The international convention is to document MCR in kilowatts, and it is the highest power available from a ship engine during average cargo and sea conditions. For this study, it is assumed that the 'Power' value in the IHS data is the best proxy for MCR power. For diesel-electric configured ships, MCR is the combined rated electric propulsion motor(s) rating, in kW for all diesel generators.

3.4.2 PROPULSION ENGINE LOAD FACTOR

Load factor for propulsion engines is estimated using the ratio of actual speed compared to the ship's maximum rated speed. Propulsion engine load factor is estimated using the Propeller Law, which shows that propulsion engine load, varies with the cube ratio of vessel actual speed and maximum rated speed. Therefore, propulsion engine load at a given speed is estimated using the following equation.

EQUATION 3.3

$$LF = (Speed_{Actual} / Speed_{Maximum})^3$$

WHERE:

LF = load factor, dimensionless

Speed$_{Actual}$ = actual speed, knots

Speed$_{Maximum}$ = maximum speed, knots

For the purpose of estimating emissions, the load factor has been capped to 1.0 so that there are no calculated propulsion engine load factors greater than 100% (i.e., calculated load factors above 1.0 are assigned a load factor of 1.0).

OGVs traveling in confined channels, such as the Houston Ship Channel, encounter additional resistance known as the phenomenon of "squat". Discussions with pilots operating in similar waterways have approximated those vessels traveling at or above 5 knots in restricted waterways would need an additional average main engine load of 10% (squat factor). Therefore, Equation 3.4 was used within the Houston ship channel for vessels traveling at or greater than 5 knots.

EQUATION 3.4

$$LFx = LF + 10\%$$

WHERE:

LFx = calculated load factor for maneuvering zone in the channel at or greater than 5 knots

LF = load factor as calculated using Equation 3.3

3.4.3 VESSEL ACTIVITY

Activity is measured in hours of operation within the geographical boundary. At-berth times are determined from the date and time stamps in the AIS data when a vessel is determined to be at a terminal. The maneuvering time within the geographical boundary is estimated using equation 3.5, which divides the segment distance traveled by ship at its over water speed.

EQUATION 3.5

$$Activity = D / Speed_{Actual}$$

WHERE:

Activity = activity, hours

D = distance, nautical miles

$Speed_{Actual}$ = actual ship speed, knots

Distance and actual speeds are derived from AIS data point locations and associated over the water speed.

3.4.4 PROPULSION ENGINE LOAD EMISSION FACTOR ADJUSTMENTS

Pollutant specific load adjustment multipliers as a function of main engine load have been established and are used in conjunction with the base emission factors shown below in Table 3.5 to estimate OGV emissions. In addition to load adjustment factors that are applied to all pollutants, emission factor adjustments (EFA) are applied to the base HC and CO emission factors of slow speed MAN and B&W engines. Please refer to 2019 GMEI[4] Report Appendix A for the equations and tables that show the values used.

4 www.porthouston.com/stewardship/environment/air-quality/

3.4.5 ENGINE EMISSION FACTORS

IMO has established NO_x emission standards for marine diesel engines[5]. NO_x emission factors are based on the IMO Tier of the vessel engines, which is based on the keel laid data included in the IHS dataset. For regulatory purposes, all diesel cycle fuel oil/marine distillate fueled engines are categorized as Tier 0 to Tier III as per the NO_x standards and by engine rated speed, in revolutions per minute or rpm, as listed below:

- **Slow speed engines:** *less than 130 rpm*
- **Medium speed engines:** *between 130 and 2,000 rpm*
- **High speed engines:** *greater than or equal to 2,000 rpm*

Emission factors for all engine types used in this study were obtained from equations or values included in EPA's document entitled Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions[6]. For the remainder of this report this document will be referred to as EPA Ports EI Guidance document.

All diesel fueled vessels in 2023 were assumed to be compliant with the IMO North American ECA requirement to use 0.1% sulfur content fuel. Table 3.5 lists the emission factors for propulsion engines using 0.1% sulfur.

Table 3.5: OGV Emission Factors for Diesel Propulsion, Steam (Boiler) Propulsion and Gas Turbine Engines, g/kW-hr

Evidence from engine manufacturers[7] and classification societies[8] suggests that Tier III propulsion engines will not meet Tier III emission standards when operating below 25% load because the exhaust heat does not reach

Vessel Type	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH4
Slow Speed Main	0	1999 and older	17.0	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	I	2000 to 2010	16.0	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	II	2011 to 2015	14.4	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	III	2016 & newer	3.4	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Medium Speed Main	0	1999 and older	13.2	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	I	2000 to 2010	12.2	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	II	2011 to 2015	10.5	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	III	2016 & newer	2.6	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Gas Turbine		All	5.7	0.01	0.01	0.10	0.20	0.59	962	0.075	0.002
Steamship Main		All	2.0	0.20	0.20	0.10	0.20	0.59	962	0.075	0.002

the necessary temperature for selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems to effectively reduce emissions. As such, when Tier III main engines operated below 25% within the emissions inventory domain, the default Tier II NO_x emission factors were used in emission calculations.

5 www.dieselnet.com/standards/inter/imo.php

6 www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance

7 MAN Diesel & Turbo, "Tier III Two-Stroke Technology."

8 DNV-GL, "NO_x Tier III Update: Choices and challenges for on-time compliance," November 2017.

Table 3.6 lists the emission factors for auxiliary engines using 0.1% sulfur.

Table 3.6: Emission Factors for Auxiliary Engines using 0.1% S, g/kW-hr

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most OGVs have one

Vessel Type	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Medium Auxiliary	0	1999 & older	13.8	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	I	2000 - 2010	12.2	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	II	2011 - 2015	10.5	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	III	2016 & newer	2.6	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
High Auxiliary	0	1999 & older	10.9	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	I	2000 - 2010	9.8	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	II	2011 - 2015	7.7	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	III	2016 & newer	2.0	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008

or more boilers used for fuel heating and for producing hot water and steam. Table 3.7 shows the emission factors used for the auxiliary boilers.

Table 3.7: Emission Factors for OGV Auxiliary Boilers using 0.1% S, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Auxiliary Boiler	All	2.0	0.20	0.19	0.10	0.20	0.59	962	0.075	0.002

Ships with dual fuel engines were contacted to find out if they used LNG in 2023 for any or all of their port calls, and in which engines. In 2023, there were 5 vessels that used LNG. Vessels using LNG in the main engines during the sea passage reported switching from LNG to conventional fuels in the main engine before slowing down to approach the port but were able to continue to run the auxiliary engines, and boiler as needed, on LNG throughout the emissions inventory domain and port stay. Dual fuel vessels require a pilot fuel for ignition, therefore an average of 7% MGO pilot fuel is assumed when vessels use LNG as a primary fuel for propulsion engines and an average of 4% MGO pilot fuel for auxiliary engines. These figures represent the average percentage developed from interviews with various dual fuel vessel operators.

Tables 3.8 and 3.9 list the emission factors for engines and steam boilers using LNG fuel per EPA's Ports EI Guidance for most pollutants, except for the SO_x EF which is from the IMO 4th GHG Study[9]. The brake specific fuel consumption (BSFC) used for LNG fuel in this report is 166 g/kWh.

9 IMO, www.imo.org/en/ourwork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

Table 3.8: Emission Factors for Propulsion Engines and Steam Boilers using LNG fuel and 7% MGO as Pilot Fuel, g/kWh

Engine Category	IMO Tier	Range Year	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_x	CO_2	N_2O	CH_4
Slow speed Propulsion	0	1999 & older	2.40	0.041	0.037	0.013	0.04	1.31	0.030	466	0.029	0.0
Slow speed Propulsion	I	2000 - 2010	2.33	0.041	0.037	0.013	0.04	1.31	0.030	466	0.029	0.0
Slow speed Propulsion	II	2011 - 2015	2.22	0.041	0.037	0.013	0.04	1.31	0.030	466	0.029	0.0
Slow speed Propulsion	III	2016 & newer	1.45	0.041	0.037	0.013	0.04	1.31	0.030	466	0.029	0.0
Medium speed Propulsion	0	1999 & older	2.13	0.041	0.038	0.013	0.04	1.29	0.033	471	0.029	0.0
Medium speed Propulsion	I	2000 - 2010	2.06	0.041	0.038	0.013	0.04	1.29	0.033	471	0.029	0.0
Medium speed Propulsion	II	2011 - 2015	1.95	0.041	0.038	0.013	0.04	1.29	0.033	471	0.029	0.0
Medium speed Propulsion	III	2016 & newer	1.39	0.041	0.038	0.013	0.04	1.29	0.033	471	0.029	0.0
Steam Boilers	na	na	1.35	0.039	0.036	0.00	0.01	1.22	0.046	492	0.075	0.0

Table 3.9: Emission Factors for Auxiliary Engines using LNG fuel and 4% MGO as Pilot Fuel, g/kWh

Engine Category	IMO Tier	Range Year	NO_x	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_x	CO_2	N_2O	CH_4
Medium Auxiliary	0	1999 & older	1.80	0.036	0.033	0.008	0.02	1.29	0.022	466	0.029	0.0
Medium Auxiliary	I	2000 - 2010	1.74	0.036	0.033	0.008	0.02	1.29	0.022	466	0.029	0.0
Medium Auxiliary	II	2011 - 2015	1.67	0.036	0.033	0.008	0.02	1.29	0.022	466	0.029	0.0
Medium Auxiliary	III	2016 & newer	1.35	0.036	0.033	0.008	0.02	1.29	0.022	466	0.029	0.0
High speed Auxiliary	0	1999 & older	1.68	0.036	0.033	0.008	0.02	1.28	0.022	466.1	0.029	0.0
High speed Auxiliary	I	2000 - 2010	1.64	0.036	0.033	0.008	0.02	1.28	0.022	466.1	0.029	0.0
High speed Auxiliary	II	2011 - 2015	1.56	0.036	0.033	0.008	0.02	1.28	0.022	466.1	0.029	0.0
High speed Auxiliary	III	2016 & newer	1.33	0.036	0.033	0.008	0.02	1.28	0.022	466.1	0.029	0.0

In addition, in 2023, there were 3 dual fueled vessels that used Methanol for their propulsion engines only when the engine load was 15% or higher. Table 3.10 shows the propulsion engine emission factors for methanol using 10% MGO as the pilot fuel. The 10% is an average pilot fuel percentage built from interviews with vessel operators.

Table 3.10: Emission Factors for Propulsion Engines using Methanol fuel and 10% MGO as Pilot Fuel, g/kWh

Engine Category	IMO Tier	Range Year	NO_X	PM_{10}	$PM_{2.5}$	DPM	HC	CO	SO_X	CO_2	N_2O	CH_4
Slow speed Propulsion	0	1999 & older	13.16	0.019	0.017	0.019	0.05	0.11	0.0401	523.6	0.003	0.0
Slow speed Propulsion	I	2000 - 2010	12.22	0.019	0.017	0.019	0.05	0.11	0.0401	523.6	0.003	0.0
Slow speed Propulsion	II	2011 - 2015	10.53	0.019	0.017	0.019	0.05	0.11	0.0401	523.6	0.003	0.0
Slow speed Propulsion	III	2016 & newer	2.63	0.019	0.017	0.019	0.05	0.11	0.0401	523.6	0.003	0.0
Medium speed Propulsion	0	1999 & older	15.98	0.018	0.017	0.018	0.06	0.14	0.0362	492.4	0.003	0.0
Medium speed Propulsion	I	2000 - 2010	17.01	0.018	0.017	0.018	0.06	0.14	0.0362	492.4	0.003	0.0
Medium speed Propulsion	II	2011 - 2015	3.38	0.018	0.017	0.018	0.06	0.14	0.0362	492.4	0.003	0.0
Medium speed Propulsion	III	2016 & newer	15.98	0.018	0.017	0.018	0.06	0.14	0.0362	492.4	0.003	0.0

3.4.6 AUXILIARY ENGINE LOAD DEFAULTS

The IHS Markit database contains limited auxiliary engine installed power information and information actual load use by mode, because neither the IMO nor the classification societies require vessel owners to provide this information. The primary data source for the Ports' EI related auxiliary engine load data is the Starcrest VBP implemented at several ports. Under VBP, vessels are boarded during their visits to ports and information is collected for the vessel and sister vessels. Specifically, during VBP, interviews with the vessel engineer are conducted to obtain data on auxiliary engine and boiler loads at various modes. Actual VBP data by vessel type, by emissions source and by mode, if available, is used when estimating auxiliary engine emissions. If VBP data for a vessel is not available, average auxiliary engine load defaults derived from VBP data by vessel type and mode for similar vessels calling the Port were used. Table 3.11 summarizes the auxiliary engine load defaults by mode used for this study by vessel subtype.

Table 3.11: Average Auxiliary Engine Load Defaults, kW

3.4.7 AUXILIARY BOILER LOAD DEFAULTS

Vessel Type	Manuevering	Berth Hotelling	Anchorage Hotelling
Auto Carrier	1,187	1,048	565
Bulk	377	369	253
Bulk - Heavy Load	1,223	272	253
Bulk - Self Discharging	625	1,000	400
Container 1000	1,280	658	1,000
Container 2000	1,823	652	525
Container 3000	1,663	790	850
Container 4000	2,463	970	954
Container 5000	2,420	989	957
Container 6000	2,566	1,086	1,229
Container 7000	2,575	1,005	880
Container 8000	2,654	1,262	1,229
Container 9000	2,853	1,116	1,183
Container 10000	1,950	1,066	1,083
General Cargo	1,098	778	180
ATB	112	411	112
RoRo	1,187	1,048	565
Tanker - Chemical	510	1,048	384
Tanker - LPG	700	1,000	500
Tanker - Asphalt	750	500	500
Tanker - Handysize	682	1,188	560
Tanker - Panamax	571	817	400
Tanker - Aframax	594	913	450
Tanker - Suzemax	679	909	553

Similar to auxiliary engine loads, the primary data source for the Ports' EI related boiler load data is VBP. If actual VBP data is not available, average boiler load defaults derived from VBP data by vessel type and mode for similar vessels calling the Port were used. The auxiliary boiler load defaults in kilowatts used for each vessel type are presented in Table 3.12.

Tankers with steam-powered cargo pumping systems have much higher auxiliary boiler usage rates when discharging cargo than they do when loading cargo. This is because, besides their usual roles, the tankers' boilers generate steam for the steam-powered liquid cargo pumps during discharge operations. However, these pumps aren't needed when loading liquid cargo, so the boiler load is much lower during this process. Specific loading and discharging activity data was not available for the tankers for each call, so the available statisticsfrom the US Army Corps of Engineers Waterborne Commerce[10] for the Houston Ship Channel and the Port of Houston was used to calculate the percentage of liquid bulk petroleum cargo that was loaded and discharged. The

10 US Army Corps of Engineers Waterborne Commerce Statistics Center (WCSC) is responsible for capturing information on vessels, tonnage, commodity, origin, and destination from vessel operating companies. https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll2/id/14579%3cbr%20/

data showed that 62% of the petroleum cargo operations were loading and the other 38% were unloading or discharging cargo. This ratio is the same as the ratio used in the 2019 GMEI.

To account for the difference in kW during loading and discharging operations in the 2023 GMEI calculations, the default boiler kW loads for tankers with steam-powered cargo systems were adjusted by incorporating a lower boiler load of 875 kW for cargo loading operations using the formula: (loading default 875 kW * 62%) + (discharging default kW * 38%). The 875 kW value is the average kW during tanker loading sourced from the VBP database. The resulting blended value, shown in Table 3.12, incorporates both loading and discharging operations proportionally for tankers with steam-powered cargo pumps.

Articulated tug barges (ATBs) do not use boilers for pumping cargo; therefore, their boiler energy default is zero. Auxiliary boilers are not typically used when the main engine load is greater than 20% due to heat recovery systems that are used to produce steam while the ship is underway. If the main engine load is less than or equal to 20%, the maneuvering boiler load defaults are used.

Table 3.12: Auxiliary Boiler Load Defaults, kW

Vessel Type	Manuevering	Berth Hotelling	Anchorage Hotelling
Auto Carrier	186	313	303
Bulk	92	123	123
Bulk - Heavy Load	94	125	125
Bulk - Self Discharging	36	144	144
Container 1000	209	455	265
Container 2000	261	363	328
Container 3000	342	522	476
Container 4000	370	485	481
Container 5000	467	565	559
Container 6000	480	610	606
Container 7000	568	660	656
Container 8000	472	598	621
Container 9000	521	653	633
Container 10000	393	540	540
General Cargo	161	207	207
ATB	0	0	0
RoRo	186	313	303
Tanker - Chemical	134	446	250
Tanker - LPG	144	187	144
Tanker - Asphalt	690	875	690
Tanker - Handysize	228	1,439	275
Tanker - Panamax	306	1,782	407
Tanker - Aframax	241	2,709	447
Tanker - Suzemax	93	3,576	446

3.5 OGV EMISSION ESTIMATES

Table 3.13 shows emissions by vessel type for PHA and Non-PHA vessel activity in 2023. Containerships and tankers have the highest emissions for PHA while tankers have the highest emissions for the private Houston Ship Channel entities (non-PHA). It also shows that in general, PHA OGV emissions account for nearly a third of the total emissions for most pollutants. For NO_x and GHG, PHA OGV emissions account for almost 40% of the total emissions.

Table 3.13: PHA and Non-PHA OGV Emissions of Criteria Pollutants by Vessel Type

Entity	Vessel Type	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO	SO_X	CO_2E
		tons						tonnes
PHA	Auto Carrier	76	0.9	0.8	2	6	2	3,526
PHA	Bulk	466	7.5	6.9	13	43	19	28,221
PHA	Containership	2,580	31.4	28.9	79	181	80	120,931
PHA	General Cargo	395	6.8	6.2	13	35	16	24,203
PHA	ATB	0	0.0	0.0	0	0	0	0
PHA	RoRo	18	0.3	0.3	1	2	1	1,142
PHA	Tanker	1,001	23.2	21.4	34	99	60	90,592
PHA		**4,536**	**70**	**65**	**143**	**365**	**178**	**268,613**
Non-PHA	Auto Carrier	7	0	0	0	1	0	354
Non-PHA	Bulk	327	5	5	9	30	13	19,280
Non-PHA	Containership	1	0	0	0	0	0	23
Non-PHA	General Cargo	487	8	8	16	44	20	29,657
Non-PHA	ATB	2	0	0	0	0	0	100
Non-PHA	RoRo	0	0	0	0	0	0	0
Non-PHA	Tanker	6,387	152	140	214	631	398	602,560
Non-PHA		**7,211**	**166**	**152**	**240**	**706**	**431**	**651,974**
Total		**11,747**	**236**	**217**	**383**	**1,071**	**609**	**920,587**
Percent PHA		**39%**	**30%**	**30%**	**37%**	**34%**	**29%**	**29%**
Percent Non-PHA		**61%**	**70%**	**70%**	**63%**	**66%**	**71%**	**71%**

Figures 3.7 and 3.8 show the distribution of NO_x emissions by vessel type for PHA-associated vessels and for the Houston Ship Channel (non-PHA), respectively. The distribution of NO_x emissions by vessel type follows the vessel call distribution closely.

Figure 3.7: 2023 PHA Distribution of NO_x Emissions by Vessel Type

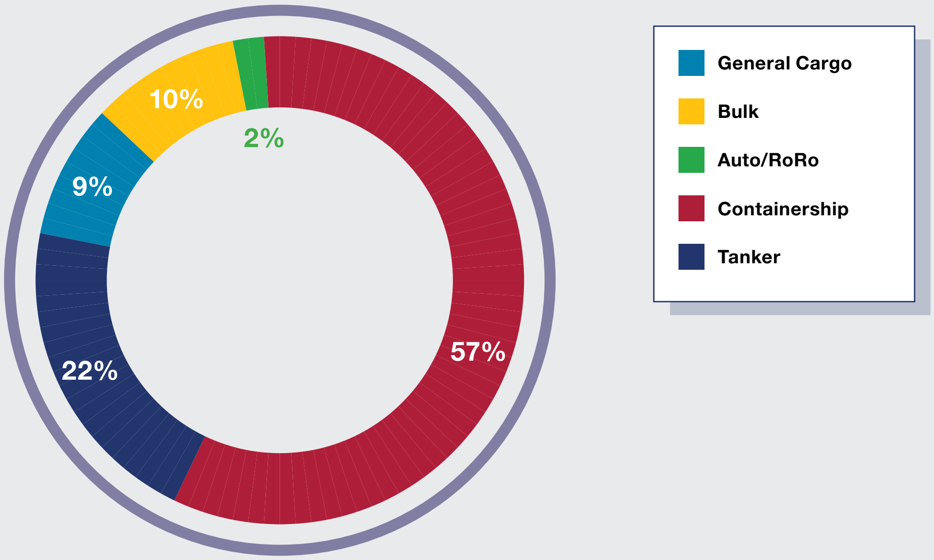


Figure 3.8: 2023 Houston Ship Channel Distribution of NO_x Emissions Vessel Type

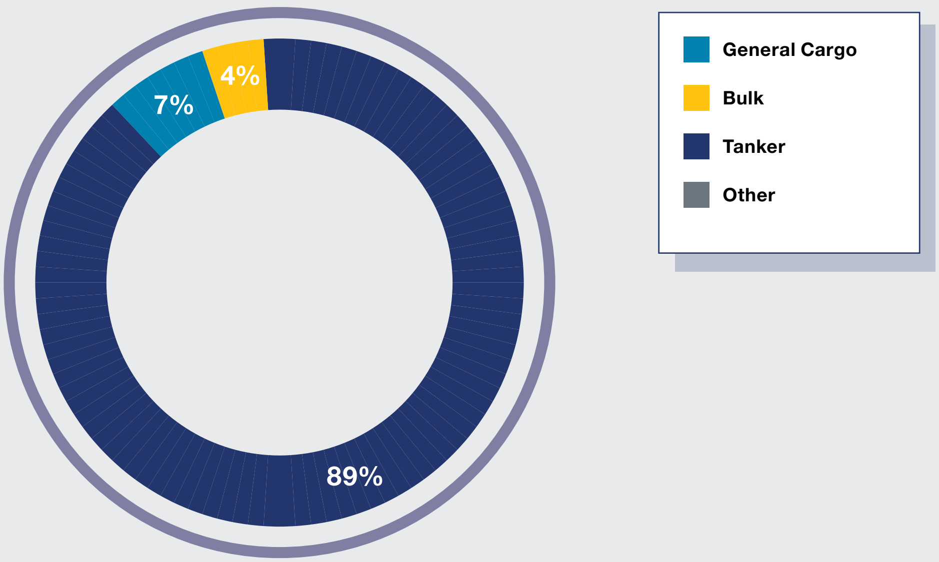


Table 3.14 presents the total PHA vessel emissions by terminal which shows that Bayport and Barbours Cut Terminals have the highest emissions. Figure 3.9 shows the distribution by terminal for NO_x emissions. The Other category is for anchorage emissions.

Table 3.14: PHA Total OGV Emissions by Terminal

Terminal	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2E
	tons						tonnes
Bayport Terminal	1,810	26	24	56	135	69	103,865
Barbours Cut Terminal	1,312	19	17	42	102	48	71,750
Turning Basin	540	9	8	17	48	22	32,965
Care Terminal	205	4	4	7	20	11	17,020
Bulk Materials Handling	49	1	1	1	4	2	2,449
Industrial Park East	57	1	1	2	5	2	3,444
Jacintoport Terminal	138	2	2	4	11	5	7,123
Manchester Wharves	106	2	2	4	10	5	7,694
Sims Bayou	37	1	1	1	4	2	3,633
Southside Wharves	134	3	2	4	12	6	9,257
Woodhouse	131	2	2	4	12	5	8,252
Other	19	0	0	1	2	1	1,162
Total	**4,536**	**70.2**	**64.6**	**143.2**	**365.4**	**177.8**	**268,613**

Figure 3.9: 2023 PHA Distribution of Total NO_x Emissions by Terminal

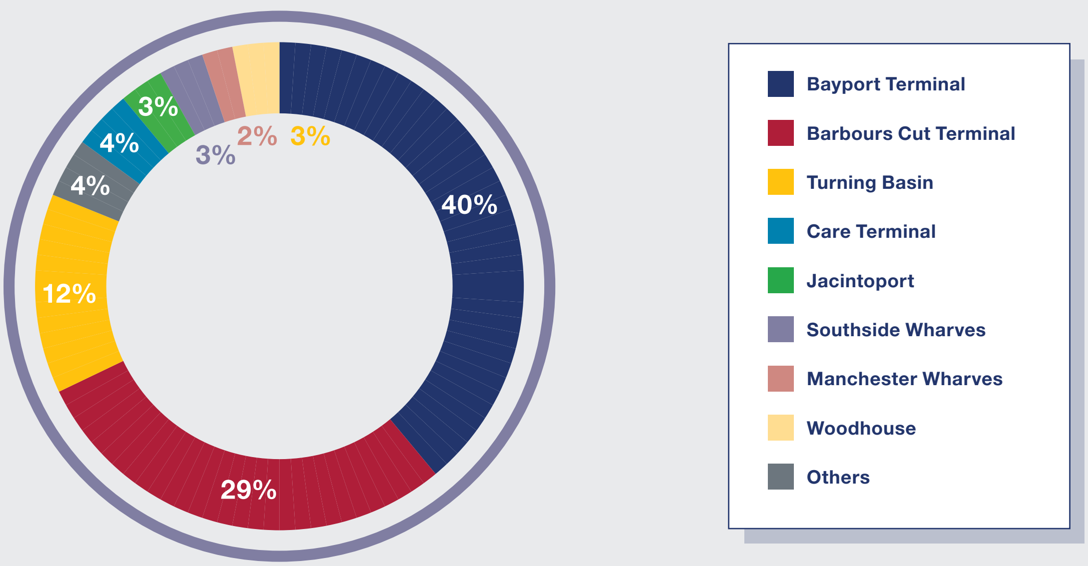


Table 3.15 presents the PHA only at-berth (hoteling) vessel emissions by terminal. It excludes maneuvering and lower speed transit emissions. Figure 3.10 shows the distribution with others including Woodhouse, Sims Bayou, Bulk Materials Terminals and Industrial Park East.

Table 3.15: PHA At-Berth OGV Emissions by Terminal

Terminal	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Bayport Terminal	569	16	14	21	56	40	59,969
Barbours Cut Terminal	389	10	9	14	37	25	38,065
Turning Basin	319	7	6	11	31	16	24,075
Care Terminal	119	3	3	5	13	9	13,354
Bulk Materials Handling	14	0	0	1	1	1	1,101
Industrial Park East	33	1	1	1	3	2	2,513
Jacintoport Terminal	47	1	1	2	4	3	3,815
Manchester Wharves	73	2	2	3	7	4	6,205
Sims Bayou	25	1	1	1	3	2	3,070
Southside Wharves	97	2	2	3	9	5	7,731
Woodhouse	78	2	2	3	8	4	6,190
Total	**1,765**	**44**	**40**	**65**	**172**	**110**	**166,087**

Figure 3.10: 2023 PHA Distribution of NO_x At-Berth Emissions by Terminal

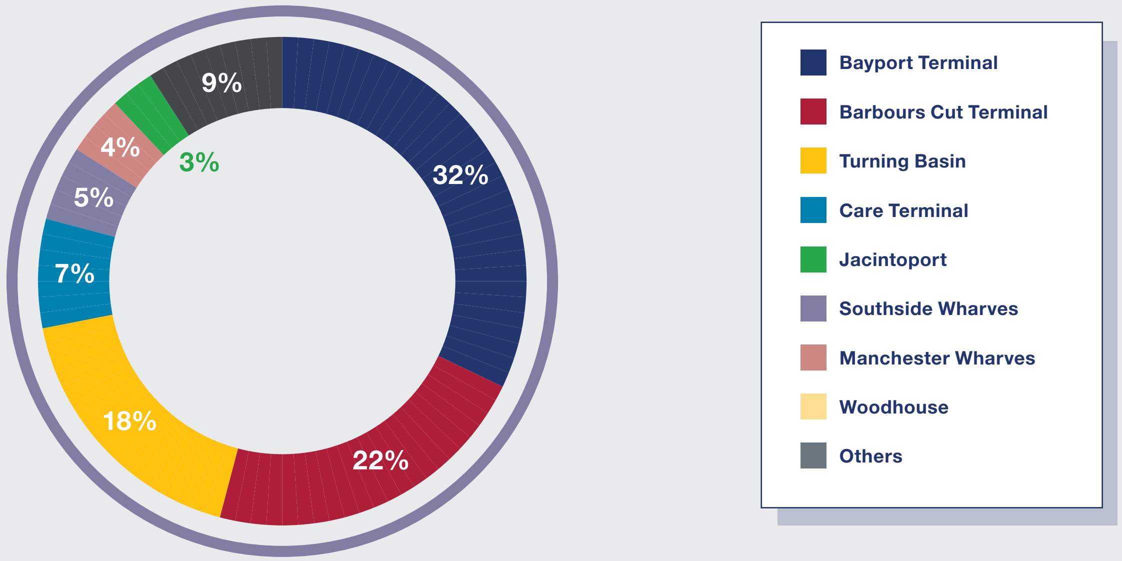


Table 3.16 presents the PHA at-berth and transit vessel emissions. The transit emissions include maneuvering and lower speed transit emissions. The at berth emissions for PHA are lower than the transit emissions for NO_x and CO, but higher for the other pollutants.

Table 3.16: PHA OGV Emissions for At Berth and Transit Mode

Terminal	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2E
	tons						tonnes
At-Berth	1,765	44	40	65	172	110	166,087
Transit	2,772	26	24	78	193	68	102,526
Total	**4,536**	**70**	**65**	**143**	**365**	**178**	**268,613**

SECTION FOUR

HARBOR VESSELS

SECTION 4 Harbor Vessels

This section presents emission estimates for the harbor vessels source category and is organized into the following subsections: source description (4.1), data and information acquisition (4.2), emissions estimation methodology (4.3), and commercial harbor craft emission estimates (4.4).

4.1 SOURCE DESCRIPTION

Emissions of propulsion and auxiliary engines from the following types of diesel-fueled commercial harbor craft were quantified:

- **Crew and supply vessels** – These supply vessels make numerous trips back and forth from a terminal or home berth to the offshore platforms.
- Harbor ferry and excursion vessels – the Sam Houston vessel is included in this category, along with other harbor vessels that move passengers.
- **Government vessels** – The government vessels include the pilot boats and PHAworkboats.
- **Tugboats** – The tugboats include vessels that assist and escort the ocean-going vessels calling at the Port, in addition to tugboats that do various types of work.
- **Towboats** – Towboats include self-propelled ocean tugs, pushboats, and towboats that tow/push barges, moving cargo such as bunker fuels and grains. Pushboats are similar to towboats, except as the name implies, they push barges rather than tow them. They can be used to move bulk liquids, scrap metal, bulk materials, rock, sand, and other materials.

Figure 4.1: Photo of Excursion Vessel

Figure 4.2: Photo of Towboat

4.2 DATA AND INFORMATION ACQUISITION

AIS data was used to identify activity (operating hours) in two zones by MMSI numbers. The zones are at berth and transit (approach) zone.

- **At berth** - *Hours in this zone were assumed for one auxiliary engine.*
- **Transit** - *Hours in this zone were assumed for one auxiliary engine and all propulsion engines on the vessel.*

IMO and MMSI numbers were joined with IHS and other publicly available data to determine number of propulsion engines, model year and horsepower rating. Information on several vessels via various towboat operators' websites was used to determine engine characteristics such as horsepower, year and engine count. The auxiliary engine characteristics were obtained for several vessels via various towboat operator's websites.

Table 4.1 summarizes the average activity in hours and engine characteristics for the 941 commercial harbor craft that visited PHA facilities in 2023. The sum of the total hours is included in the table to show that the vessels that spent the most time in the study area are towboats and tugboats.

Table 4.1: 2023 PHA Harbor Craft Averages by Commercial Harbor Craft Type

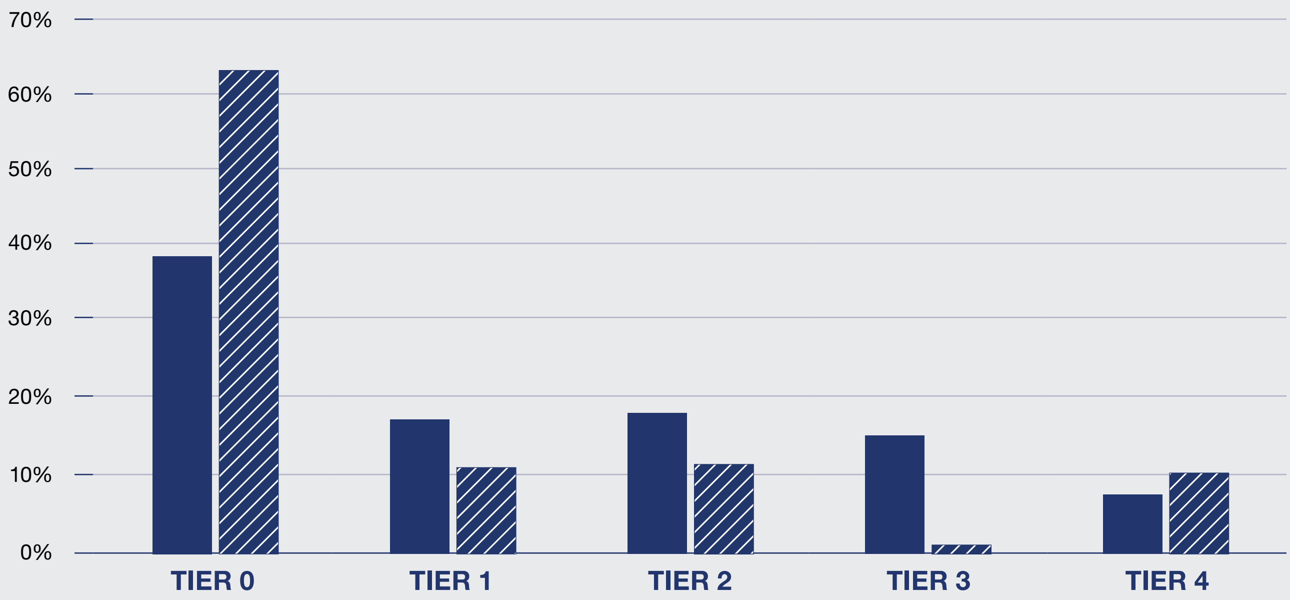
Vessel Type	PHA Vessel Trips	PHA Vessel Count	Average Berth Hours	Average Transit Hours	Sum Total Hours	Auxiliary Engine kW	Propulsion Engine kW	Average Engine Year
Crew & supply	35	11	24	2.0	916	70	1,415	2006
Government/Pilot	33	5	127	8.0	4,202	69	1,009	2005
Harbor Ferry	25	7	35	3.5	955	99	533	2008
Miscellaneous	61	19	58	1.2	3,607	70	947	2006
Towboat/Pushboat	2,685	705	13	1.0	37,040	69	879	2004
Tugboat	858	193	67	6.4	62,282	71	1,359	2002
Work Boat	7	1	654	1.1	4,585	71	520	na
Total	**3,704**	**941**						
2019	1,040	323						
2023 vs 2019	72%	66%						

Table 4.2 summarizes the PHA main engine tier distribution by vessel type. The percentages are based on actual data without defaults for discrete vessels that called PHA terminals. When the engine data was not available, defaults were used based on the known engine data available. Table 4.2 shows that in 2023, for vessels with known engine year, there are significantly less Tier 0 engines. This is due to both fleet turnover and improved data collection to locate as many engine characteristics as possible through the use of various websites and data collected from prior inventories.

Table 4.2: 2023 PHA Main Engine Tier by Commercial Harbor Craft Type

VESSEL TYPE	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Crew and supply	36%	9%	55%	0%	0%
Ferry and excursion	100%	0%	0%	0%	0%
Gov/Pilot/Misc/Workboat	33%	47%	20%	0%	0%
Towboat/Pushboat	34%	16%	21%	21%	8%
Tugboat	60%	22%	7%	1%	11%
Total	**39%**	**18%**	**19%**	**16%**	**8%**
2019	**64%**	**12%**	**12%**	**2%**	**11%**

Figure 4.3: 2023 vs 2019 PHA Main Engine Tiers Distribution



4.3 EMISSION ESTIMATION METHODOLOGY

The basic equation used to estimate harbor vessels emissions is:

EQUATION 4.1

$$E = Power \times Activity \times LF \times EF \times Fuel\ Adjustment$$

<u>WHERE:</u>

E = emissions, g/year

Power = rated power of the engine, hp or KW

Activity = engine operating hours, hours/year

LF = load factor (ratio of average load used during normal operations compared to full load at maximum rated horsepower), dimensionless

EF = emission factor for propulsion and auxiliary engines by engine tier, g/kW-hr

Fuel adjustment = EF is adjusted if the EF used is based on fuel that is different than the actual fuel used.

If available, vessel-specific rated horsepower of the engine and hours were used otherwise averages by vessel type as shown in Table 4.1 were used. The calculated emissions were converted to tons per year by dividing the emissions by 2,000 lb/ton x 453.59 g/lb. Fuel adjustment was applied to estimate NO_x emissions. Since the harbor craft emission factors are based on ULSD fuel and in 2023 all harbor craft in PHA and the non-PHA region complied with the Texas Low Emission Diesel (TxLED) Program which has lower aromatic content and a high cetane value, an NO_x reduction of 6.2% was applied.

The emission factors used for harbor craft are listed in Tables 4.3 and 4.4 for fueled propulsion and auxiliary engines, respectively. The emission factors units listed in the following emission factor tables are in grams per kilowatt-hour. These emissions factors were obtained from EPA's Ports EI Guidance Document[11].

Table 4.3: Harbor Craft Emission Factors for Propulsion Engines using ULSD, g/kW-hr

Vessel Type	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Tier 0 Engines										
37 < kW ≤ 600	<2003	10.08	0.24	0.23	0.29	1.62	0.01	679	0.03	0.01
600 < kW ≤ 1000	<2003	10.25	0.21	0.20	0.28	1.65	0.01	679	0.03	0.01
1000 < kW ≤ 1400	<2003	10.45	0.22	0.21	0.27	1.71	0.01	679	0.03	0.01
1400 < kW ≤ 2000	<2003	11.80	0.20	0.19	0.24	2.03	0.01	679	0.03	0.01
2000 < kW ≤ 3700	<2003	13.36	0.21	0.20	0.14	2.48	0.01	679	0.03	0.01
2000 < kW ≤ 3700	2004-2006	10.55	0.21	0.20	0.14	2.48	0.01	679	0.03	0.01
3, 701+	<2003	13.36	0.21	0.20	0.14	2.48	0.01	679	0.03	0.01
3, 701+	2004-2006	10.55	0.21	0.20	0.14	2.48	0.01	679	0.03	0.01
Tier 1 Engines										
37 < kW ≤ 600	2004-2006	6.50	0.13	0.12	0.23	1.17	0.01	679	0.03	0.01
600 < kW ≤ 1000	2004-2006	7.83	0.16	0.16	0.24	1.44	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2004-2006	7.28	0.15	0.14	0.22	1.39	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2004-2006	9.66	0.20	0.19	0.24	2.03	0.01	679	0.03	0.01
Tier 2 Engines										
37 < kW ≤ 600	2007-2012	6.06	0.12	0.12	0.22	1.10	0.01	679	0.03	0.01
600 < kW ≤ 1000	2007-2012	6.06	0.12	0.12	0.20	1.12	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2007-2011	6.22	0.14	0.13	0.19	1.18	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2007-2011	6.79	0.18	0.18	0.18	1.40	0.01	679	0.03	0.01
2000 < kW ≤ 3700	2007-2015	8.33	0.31	0.30	0.14	2.00	0.01	679	0.03	0.01
3, 701+	2007-2015	8.33	0.31	0.30	0.14	2.00	0.01	679	0.03	0.01
Tier 3 Engines										
37 < kW ≤ 600	2013	5.67	0.11	0.10	0.18	1.10	0.01	679	0.03	0.01
37 < kW ≤ 600	2014-2021	4.69	0.07	0.07	0.11	1.10	0.01	679	0.03	0.01
600 < kW ≤ 1000	2013	5.30	0.09	0.09	0.15	1.12	0.01	679	0.03	0.01
600 < kW ≤ 1000	2014-2021	4.74	0.07	0.07	0.10	1.12	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2013	5.66	0.10	0.10	0.16	1.18	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2014-2016	4.83	0.07	0.07	0.10	1.18	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2013	5.40	0.10	0.10	0.10	1.40	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2014-2015	5.27	0.10	0.10	0.10	1.40	0.01	679	0.03	0.01
Tier 4 Engines										
600 < kW ≤ 1000	2017+	1.3	0.03	0.03	0.04	1.1	0.01	679	0.031	0.01
1000 < kW ≤ 1400	2017+	1.3	0.03	0.03	0.04	1.2	0.01	679	0.031	0.01
1400 < kW ≤ 2000	2016+	1.3	0.03	0.03	0.03	1.40	0.01	679	0.03	0.01
2000 < kW ≤ 3700	2016+	1.3	0.03	0.03	0.02	2.00	0.01	679	0.03	0.01
3, 701+	2016+	1.3	0.03	0.03	0.02	2.00	0.01	679	0.03	0.01

11 www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance

Table 4.4: Harbor Craft Emission Factors for Auxiliary Engines using ULSD, g/kW-hr

Vessel Type	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Tier 0 Engines										
37 < kW ≤ 600	<2003	10.08	0.29	0.28	0.30	1.57	0.01	679	0.03	0.01
600 < kW ≤ 1000	<2003	10.41	0.21	0.21	0.28	1.62	0.01	679	0.03	0.01
1000 < kW ≤ 1400	<2003	10.95	0.19	0.19	0.28	1.78	0.01	679	0.03	0.01
1400 < kW ≤ 2000	<2003	10.08	0.24	0.23	0.28	1.80	0.01	679	0.03	0.01
Tier 1 Engines										
37 < kW ≤ 600	2005-2006	6.10	0.16	0.15	0.26	0.96	0.01	679	0.03	0.01
600 < kW ≤ 1000	2004-2006	7.62	0.17	0.16	0.25	1.32	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2004-2006	9.19	0.19	0.19	0.28	1.78	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2004-2006	9.20	0.19	0.18	0.28	1.80	0.01	679	0.03	0.01
Tier 2 Engines										
37 < kW ≤ 600	2007-2012	5.96	0.15	0.15	0.25	0.93	0.01	679	0.03	0.01
600 < kW ≤ 1000	2007-2011	6.10	0.14	0.13	0.22	0.90	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2007-2011	6.10	0.14	0.13	0.22	0.90	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2007-2011	6.10	0.14	0.13	0.22	0.90	0.01	679	0.03	0.01
Tier 3 Engines										
37 < kW ≤ 600	2013+	4.58	0.08	0.08	0.13	0.93	0.01	679	0.03	0.01
600 < kW ≤ 1000	2014-2017	4.82	0.08	0.08	0.12	0.90	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2013-2015	4.88	0.08	0.08	0.12	0.90	0.01	679	0.03	0.01
Tier 4 Engines										
600 < kW ≤ 1000	2018+	1.30	0.03	0.03	0.04	0.90	0.01	679	0.03	0.01
1000 < kW ≤ 1400	2017+	1.30	0.03	0.03	0.04	0.90	0.01	679	0.03	0.01
1400 < kW ≤ 2000	2016+	1.30	0.03	0.03	0.04	0.90	0.01	679	0.03	0.01

Engine load factors represent the average load of an engine or the percentage of rated engine power that is used during the engine's normal operation. Table 4.5 summarizes the average engine load factors that were used in this inventory for the harbor craft vessel types for their propulsion and auxiliary engines. The load factors are consistent with the latest EPA Ports EI Guidance document.

Table 4.5: Commercial Harbor Craft Load Factors

HARBOR Craft Type	PROPULSION Engine	AUXILIARY Engine
Crew and supply	0.45	0.43
Ferry and excursion	0.42	0.43
Government	0.45	0.43
Pilot boat	0.51	0.43
Tugboat	0.50	0.43
Towboat and pushboat	0.68	0.43
Work boat	0.45	0.43

4.4 COMMERCIAL HARBOR CRAFT EMISSION ESTIMATES

Table 4.6 presents the PHA emissions for commercial harbor craft by vessel type which show tugboats and towboats with the highest emissions compared to other vessel types. Table 4.7 presents the PHA emissions by terminal for harbor craft. Table 4.8 presents the non-PHA commercial harbor craft emissions which include harbor craft that only visited non-PHA facilities.

Table 4.6: 2023 PHA Commercial Harbor Craft Emissions

VESSEL type	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Crew and supply	1	0.0	0.0	0.0	0.2	0.0	87
Ferry and excursion	1	0.0	0.0	0.0	0.1	0.0	56
Gov/Pilot/Misc/Workboat	8	0.2	0.2	0.2	1.4	0.0	551
Tugboat	61	1.7	1.6	1.4	24.0	0.1	8,444
Towboat and pushboat	33	0.8	0.7	1.1	6.4	0.0	2,997
Total	**103**	**2.6**	**2.6**	**2.8**	**32.1**	**0.1**	**12,136**

Table 4.7: 2023 PHA Commercial Harbor Craft Emissions by Terminal

TERMINAL	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Barbours Cut Terminal	15	0	0	0	5	0	1,740
Bayport Terminal	26	1	1	1	8	0	3,018
Bulk Materials Handling	2	0	0	0	0	0	186
CARE Terminal	6	0	0	0	2	0	682
Industrial Park East	4	0	0	0	1	0	435
Jacintoport Terminal	17	0	0	0	5	0	2,037
Manchester Wharves	2	0	0	0	1	0	260
Sims Bayou	11	0	0	0	3	0	1,267
Southside Wharves	8	0	0	0	2	0	931
Turning Basin	13	0	0	0	4	0	1,512
Woodhouse	1	0	0	0	0	0	67
Total	**103**	**3**	**3**	**3**	**32**	**0**	**12,136**

Table 4.8: 2023 Non-PHA Commercial Harbor Craft Emissions

VESSEL type	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Crew and supply	82	2.2	2.1	2.3	17.5	0.1	7,747
Ferry and excursion	23	0.5	0.5	0.9	4.2	0.0	2,492
Gov/Pilot/Misc/Workboat	417	10.0	9.7	13.4	91.2	0.4	39,135
Tugboat	1,377	31.3	30.4	35.1	329.4	1.2	119,824
Towboat and pushboat	3,237	71.7	69.6	98.2	670.1	3.0	299,324
Total	**5,136**	**115.7**	**112.3**	**150.0**	**1,112.4**	**4.7**	**468,522**

Figures 4.3 and 4.4 show the distribution of NO_x emissions by commercial harbor craft type for PHA- and for the Houston Ship Channel (non-PHA), respectively. The Other category includes ferry, excursion, crew and supply vessels, government, pilot, miscellaneous and workboats.

Figure 4.3: 2023 PHA Distribution of NO_x Emissions by Commercial Harbor Craft

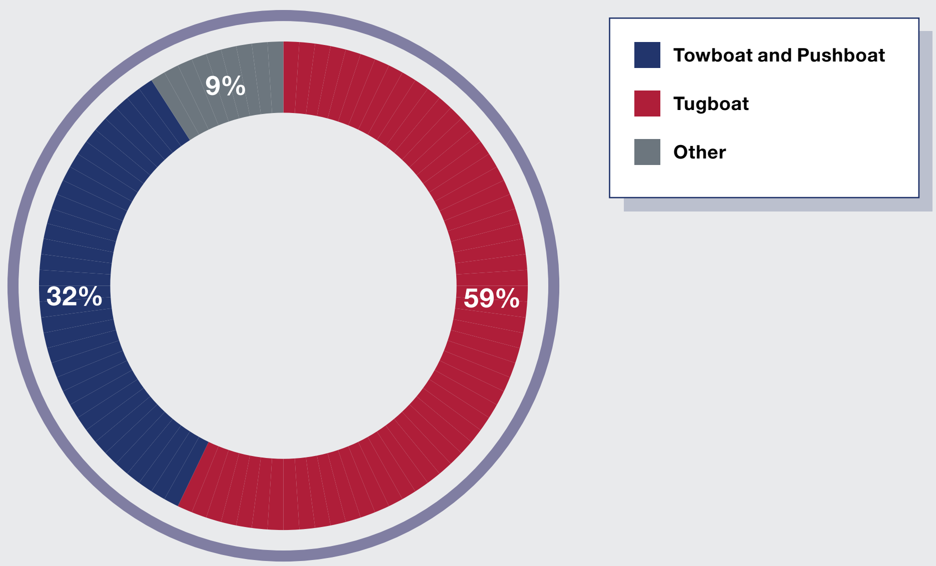


Figure 4.4: 2023 Houston Ship Channel Distribution of NO_x Emissions by Commercial Harbor Craft

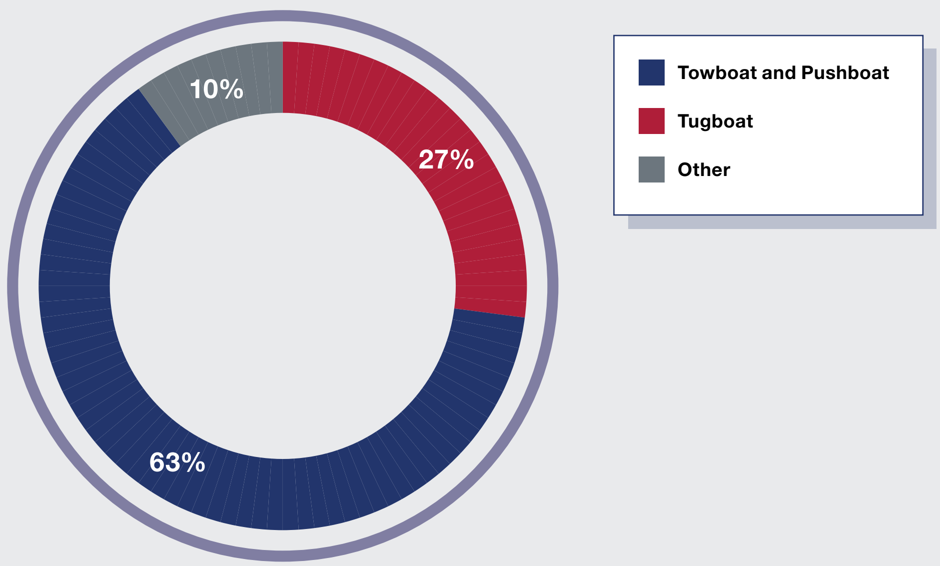
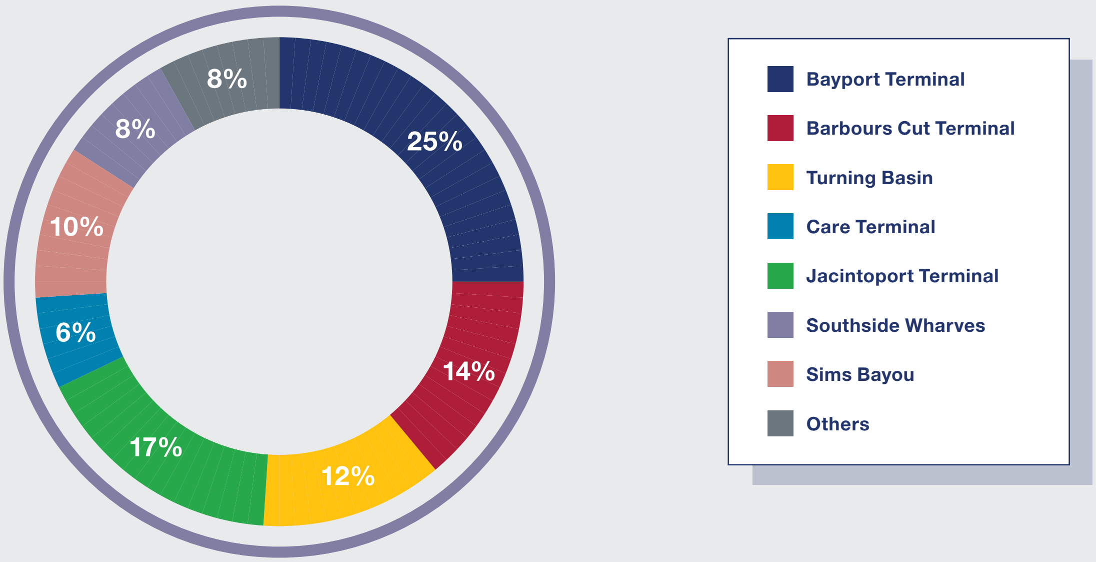


Figure 4.5 shows the distribution of NOx emissions by commercial harbor craft type for PHA terminals only. The Other category includes Bulk Material Handling, Manchester Wharves, Woodhouse, and Industrial Park.

Figure 4.5: 2023 PHA Commercial Harbor Craft Distribution of NO_x Emissions by Terminal



SECTION FIVE

CARGO HANDLING EQUIPMENT

SECTION 5 CARGO HANDLING EQUIPMENT

This section presents emission estimates for the cargo handling equipment source category and is organized into the following subsections: source description (5.1), data and information acquisition (5.2), emissions estimation methodology (5.3), and the cargo handling equipment emission estimates (5.4).

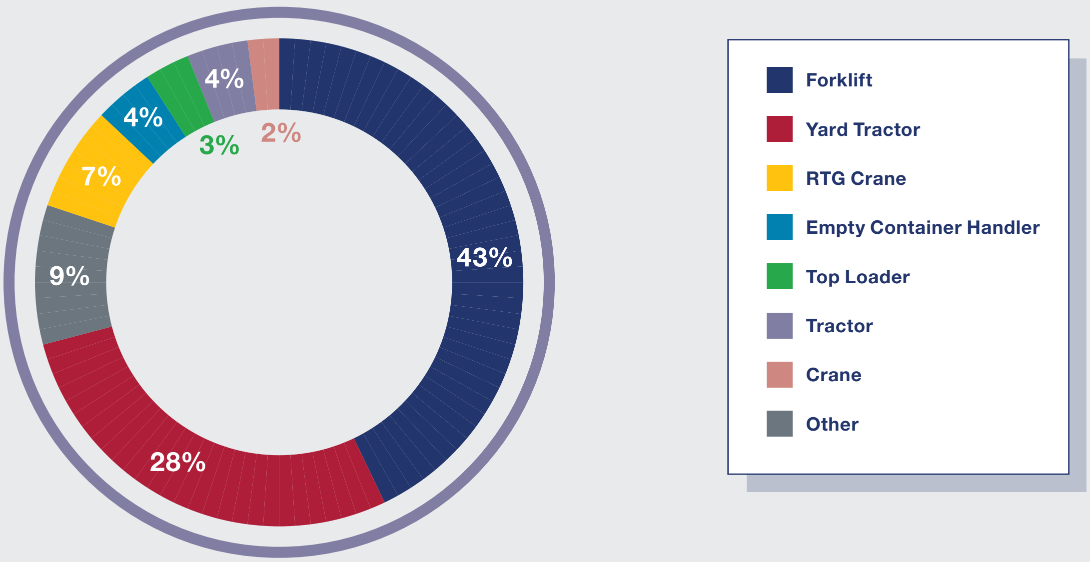
5.1 SOURCE DESCRIPTION

Emissions from the following types of diesel-fueled cargo handling equipment (CHE) were quantified for PHA facilities which only include public facilities that operate tenant equipment and/or PHA owned equipment:

- Backhoe
- Crane
- Bulldozer
- Forklift
- Empty container handler
- Generator
- Grader
- Light Tower
- Manlift
- Telehandler
- Tractor
- Top loader
- Yard tractor
- Reach stacker
- Railcar pusher
- Skid steer loader
- Sweeper
- Truck
- Rubber tired gantry (RTG) crane
- Ship to shore (STS) cranes

In 2023, new facilities and equipment operators were added to the list which increased the equipment count by 17% from 2019 GMEI.Figure 5.1 presents the distribution of the 1,610 pieces of cargo handling equipment by type inventoried for PHA in 2023. Most of the pieces of equipment are forklifts (43%) and yard tractors (28%), followed by "other" (9%), RTG cranes (7%), empty container handler and tractors (4%). Other equipment in Figure 5.1 includes: ship to shore cranes, manlift, tractor, reach stacker, sweeper, dozer, light tower, wheel loader, truck (fuel and water), excavator, front end loader, telehandler, railcar mover, backhoe, skid steer loader, generator, and grader.

Figure 5.1: 2023 Distribution of Cargo Handling Equipment by Type



Figures 5.2-5.5 are photos of some of the equipment types that operate at the terminals.

Figure 5.2: Photo of Forklift

Figure 5.3: Photo of RTG Crane

Figure 5.4: Photo of Yard Tractor

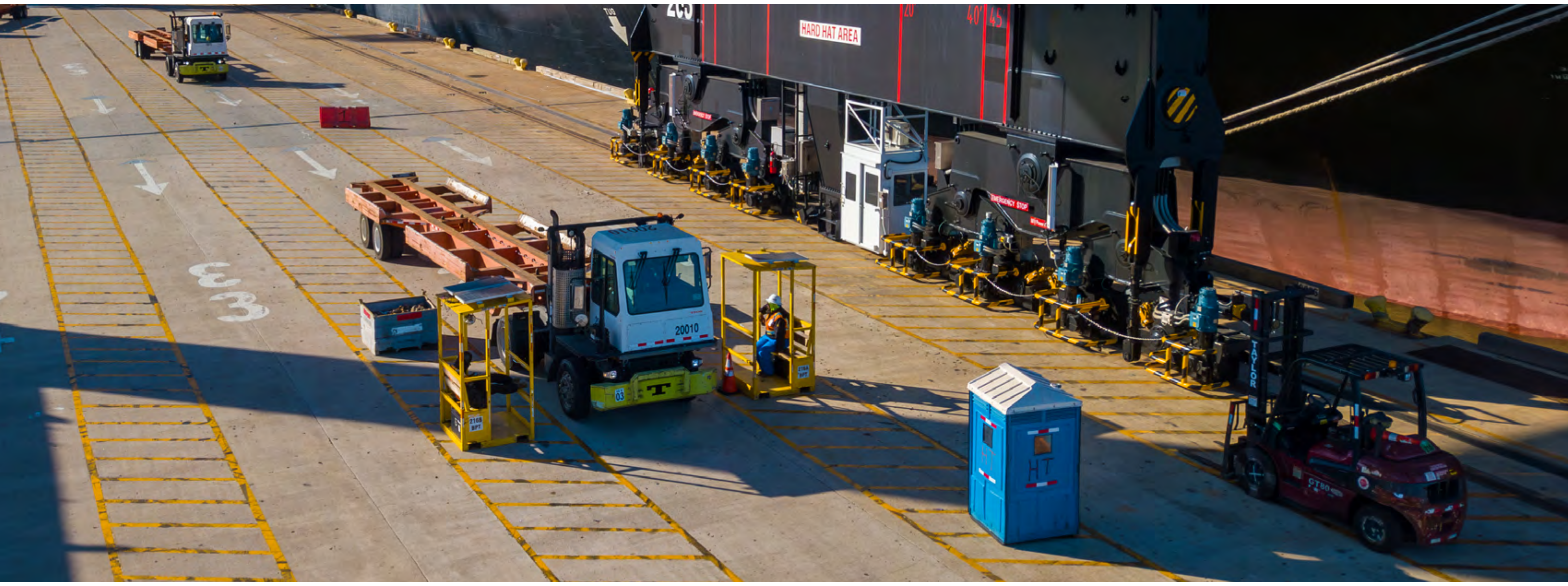
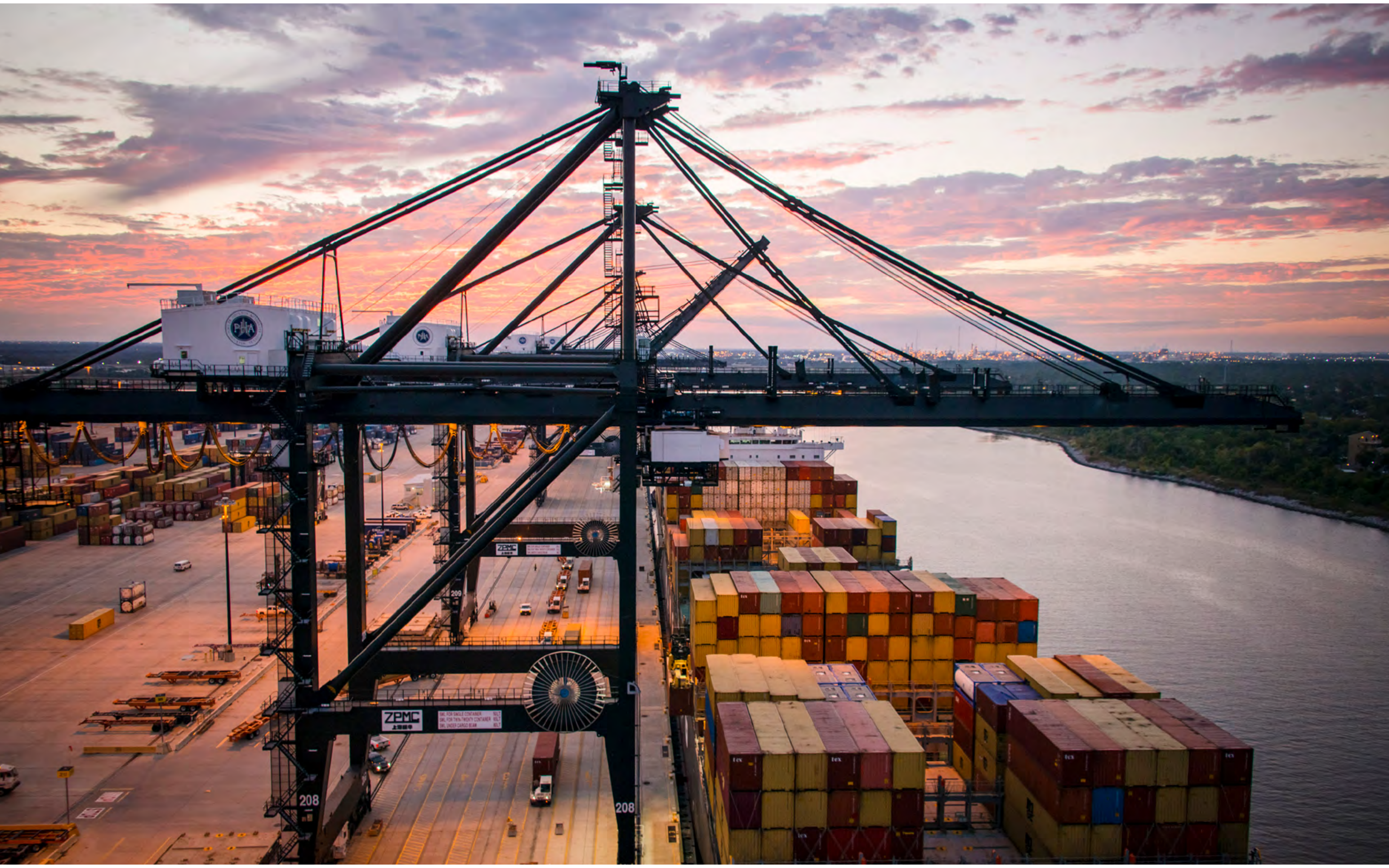


Figure 5.5: Photo of Ship to Shore Crane (Wharf Crane)



5.2 DATA AND INFORMATION ACQUISITION

Table 5.1 summarizes the characteristics of the cargo handling equipment operating at PHA terminals in 2023, including PHA-owned and operated equipment and equipment owned by the tenants and stevedores. The terminals and stevedores provided their equipment fleet along with hours of use. Averages by equipment and fuel type are used as default values when equipment specific data is not available.

Figures 5.6 and 5.7 summarize the distribution of diesel cargo handling equipment's engines by noroad standards[12] (Tier 0, 1, 2, 3, 4 interim, and 4 final) based on model year and horsepower range. In addition to the diesel equipment, the inventory includes 39 propane (forklifts and a sweeper) and gasoline equipment and 30 electric equipment (see Table 5.1). The unknown is for equipment that did not provide horsepower and/or model year. To estimate emissions, defaults based on the known information were used for equipment with unknown horsepower and/or model year.

12 EPA, Nonroad Compression-Ignition Engines- Exhaust Emission Standards, June 2004

Table 5.1: 2023 Equipment Characteristics

EQUIPMENT	COUNT #	MODEL YEAR Average	HORSEPOWER Average	ANNUAL HOURS Average
Diesel				
Backhoe	2	2011	84	176
Bulldozer	8	2014	436	1,491
Crane	37	1986	222	1,187
Empty container handler	60	2014	222	2,041
Excavator	6	2013	409	1,076
Forklift	665	2009	116	780
Generator	3	2003	137	169
Grader	1	2008	176	147
Hybrid RTG	31	2019	164	1,728
Light tower	11	2009	14	598
Loader	15	2010	160	392
Manlift	10	2011	62	576
Railcar pusher	9	2008	201	952
Reach stacker	15	2013	348	1,920
RTG crane	85	2008	682	4,412
Skid steer loader	5	2019	74	192
Sweeper	11	2014	7	288
Telehandler	9	2012	166	1,510
Top loader	40	2009	287	1,060
Tractor	59	2018	49	541
Truck	8	2000	351	428
Yard tractor	451	2013	188	1,794
Gasoline				
Miscellaneous	7	2022	16	3,650
Propane				
Forklift	31	2016	82	1,069
Sweeper	1	na	55	240
Electric				
Forklift	1	na	na	na
Manlift	2	na	na	na
STS crane	27	na	na	na
Total	**1,610**			

PORT HOUSTON
THE INTERNATIONAL PORT OF TEXAS

Figure 5.6: 2023 Diesel Equipment Tier Count Distribution

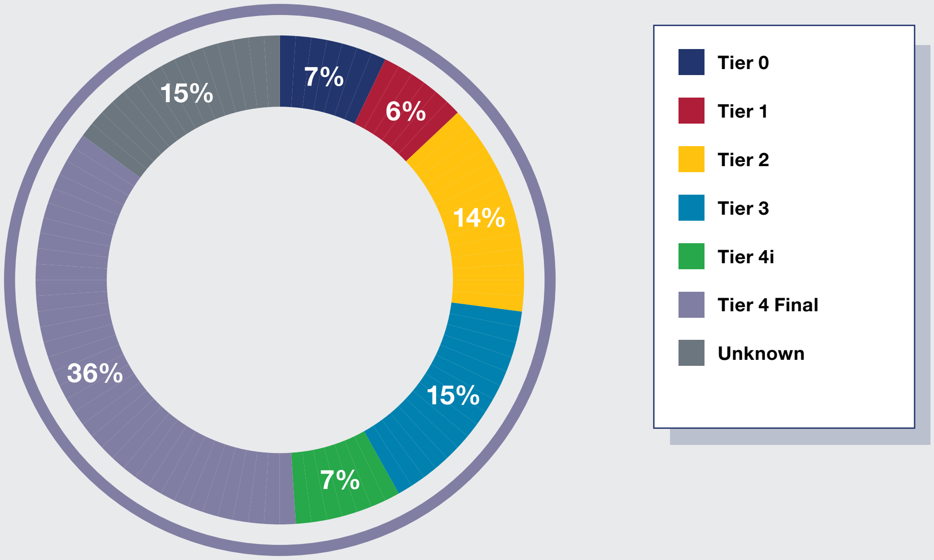
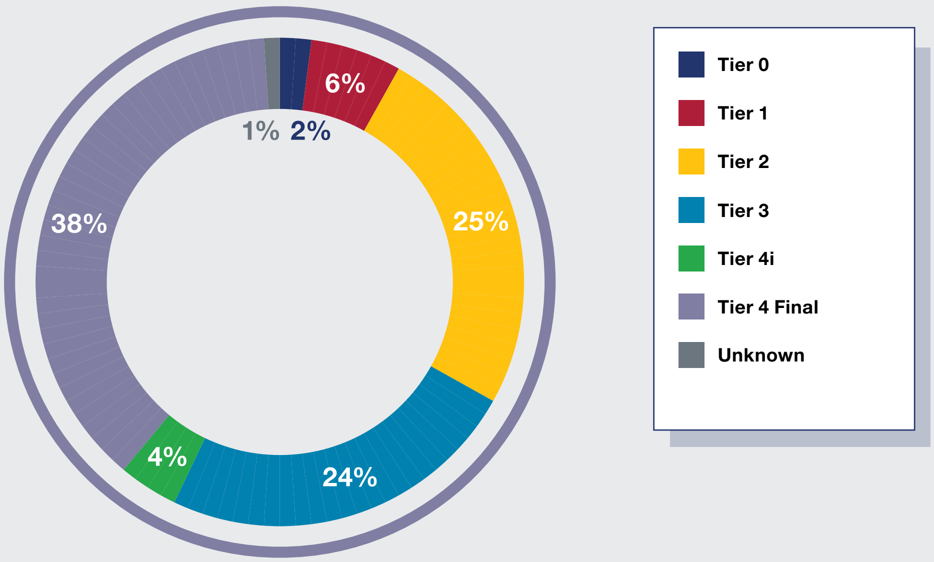


Figure 5.7: 2023 PHA-owned and Operated Diesel Equipment Tier Count Distribution



In 2023, for both the stevedores/tenant and port-owned and operated equipment (Figures 5.6), 58% of the diesel equipment had Tier 3 or Tier 4 engines, the newest and cleanest engines. For PHA-operated equipment only (Figure 5.7), 66% of the diesel equipment had Tier 3 or newer engines compared to 47% in 2019.

5.3 EMISSION ESTIMATION METHODOLOGY

Emissions were estimated using the MOVES4 emission estimating model[13] which is designed to accommodate a wide range of off-road equipment types and recognize a defined list of equipment designations. The pieces of terminal equipment identified at the terminals were categorized into the most closely corresponding MOVES4 equipment type. Table 5.2 presents equipment types by Source Classification Code (SCC), load factor, and MOVES4 / NONROAD category common name.

Table 5.2: MOVES / NONROAD Engine Source Categories

EQUIPMENT Type	SCC	LOAD Factor	NONROAD Category
Backhoe, loader	2270002066	0.21	Tractors/Loaders/Backhoes
Bulldozer	2270003040	0.43	General industrial equipment
Crane	2270002045	0.43	Cranes
Empty container handler	2270003040	0.43	General industrial equipment
Excavator	2270002036	0.59	Excavators
Forklift, diesel	2270003020	0.59	Forklifts
Manlift	2270003010	0.21	Aerial lifts
Rail pusher	2270003040	0.43	General industrial equipment
RTG cranes	2270003050	0.21	Other material handling equipment
Water and fuel truck	2270002051	0.59	Off-highway trucks
Portable light set	2270002027	0.43	Signal board / light plant
Skid-steer loader	2270002072	0.21	Skid-steer loader
Sweeper	2270003030	0.43	Sweeper / scrubber
Reach stacker	2270003040	0.43	General industrial equipment
Top handler	2270003040	0.43	General industrial equipment
Tractor	2270002075	0.59	Off-highway tractor
Yard tractor	2270003070	0.39	Terminal tractor

13 EPA MOVES, www.epa.gov/otaq/models/moves/

The general form of the equation used for estimating CHE emissions is:

EQUATION 5.1

$$E = Power \times Activity \times LF \times EF \times CF \times Fuel\ Adjustment$$

WHERE:

E = emissions, grams or tons/year

Power = rated power of the engine, hp or kW

Activity = equipment's engine activity, hr/year

LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks), dimensionless

EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr

CF = control factor to reflect changes in emissions due to installation of emission reduction technologies or use of certified on-road engine instead of off-road engine not originally reflected in the emission factors.

Fuel Adjustment = Fuel Adjustments are used if the EF used is based on fuel that is different than the actual fuel used. For 2023 EI, MOVES EFs obtained were based on ULSD and a fuel factor was used to adjust NOx for TxLED fuel.

Equipment specific power, fuel type, and activity (hours of use) was obtained from the Port and tenants during data collection. Defaults were used if the power or activity information was missing. For each calendar year, the MOVES4 model has the option to output emission factors in grams/hp-hr by calendar year for each of the MOVES4 equipment types by horsepower groups and model year. The model year groups are aligned with EPA's nonroad equipment emissions standards. MOVES4 emission factors reflect the actual ULSD fuel used in 2023. The estimates of CHE emissions from each piece of equipment are based on its model year, horsepower rating, annual hours of operation, and equipment-specific load factor assumptions.

The load factors by NONROAD category as used by MOVES4 are listed in Table 5.2. Except for yard hustlers, load factors for all other equipment were obtained from MOVES4. MOVES4 was run for calendar year (CY) 2023 with default conditions to obtain emission factors in grams/hp-hr. The MOVES4 EFs are based on ULSD fuel, the NOx was adjusted to take into account the TxLED fuel (6% reduction).

5.4 CARGO HANDLING EQUIPMENT EMISSION ESTIMATES

Tables 5.3 and 5.4 present the estimated cargo handling equipment emissions. Rubber tired gantry (RTG) cranes have the highest emissions, followed by forklifts and yard tractors.

Table 5.3: 2023 PHA Cargo Handling Equipment Emissions by Equipment Type

Terminal	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E (tonnes)
Rub-trd Gantry Crane	164.8	20.8	19.4	9.4	50.8	0.1	34,019
Forklift	133.9	17.9	17.4	16.1	49.1	0.1	20,589
Yard tractor	84.9	9.6	9.3	12.9	43.5	0.1	31,793
Crane	42.8	4.7	4.5	4.3	20.8	0.0	2,301
Empty Container Handler	12.3	0.6	0.6	0.9	2.7	0.0	6,309
Top Handler	8.9	0.5	0.5	0.6	2.3	0.0	2,757
Reach Stacker	8.4	0.3	0.3	0.4	2.3	0.0	2,360
Truck	5.0	0.3	0.3	0.6	1.4	0.0	383
Bulldozer	3.8	0.2	0.2	0.2	1.1	0.0	1,450
Rail Pusher	2.3	0.2	0.2	0.2	0.8	0.0	370
Tractor	2.1	0.1	0.1	0.2	0.9	0.0	474
Excavator	1.6	0.1	0.1	0.1	0.8	0.0	857
Hybrid RTG	1.3	0.1	0.1	0.1	0.5	0.0	1,148
Telehandler	1.0	0.0	0.0	0.0	0.2	0.0	580
Loader	0.5	0.1	0.1	0.1	0.4	0.0	139
Manlift	0.5	0.1	0.1	0.1	0.6	0.0	59
Miscellaneous	0.4	0.0	0.0	1.2	69.3	0.0	233
Sweeper	0.2	0.0	0.0	0.0	0.1	0.0	109
Light Tower	0.2	0.0	0.0	0.0	0.1	0.0	24
Generator	0.2	0.0	0.0	0.0	0.0	0.0	16
Grader	0.0	0.0	0.0	0.0	0.0	0.0	8
Skid Steer Loader	0.0	0.0	0.0	0.0	0.0	0.0	10
Backhoe	0.0	0.0	0.0	0.0	0.0	0.0	4
Total	**475.2**	**55.7**	**53.2**	**47.6**	**247.8**	**0.4**	**105,993**

Figure 5.8 shows that 65% of the NOx emissions are emitted by the older Tier 0-Tier 2 diesel engines.

Figure 5.8: 2023 PHA Diesel CHE NOx Emissions by Tier

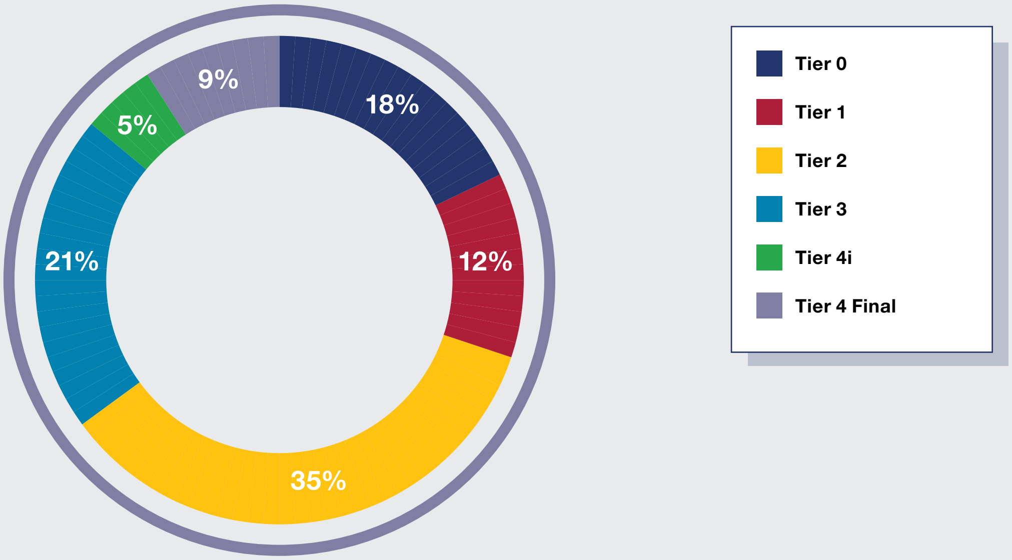


Figure 5.9 shows that 70% of the PM2.5 emissions are emitted by the older Tier 0-Tier 2 diesel engines.

Figure 5.9: 2023 PHA Diesel CHE PM2.5 Emissions by Tier

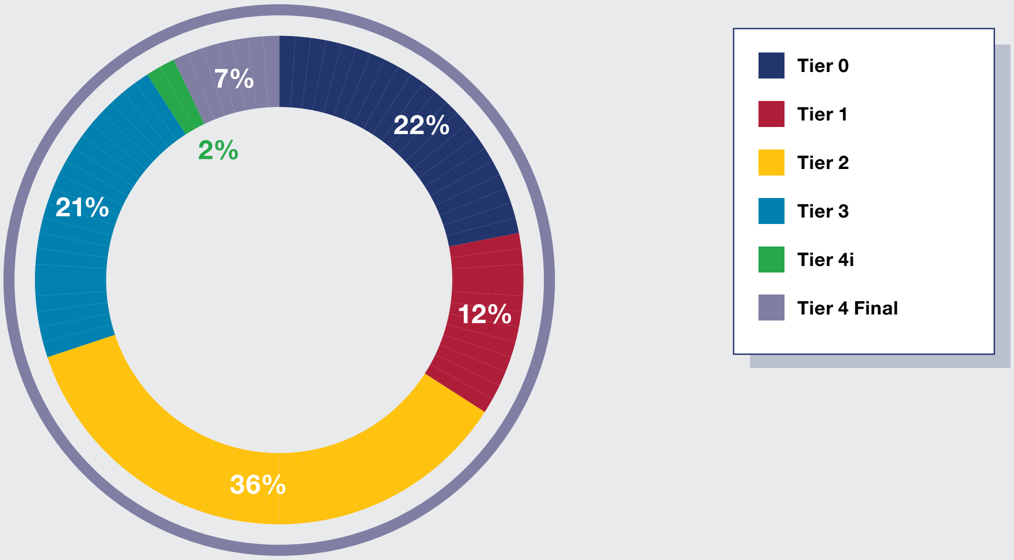


Table 5.4 presents the CHE emissions by terminal. In 2023, Barbour's Cut, Turning Basin and Bayport Terminals had the highest CHE emissions for total PHA. Care Terminal was not included in the 2019 inventory but added to the 2023 inventory. For 2023, more stevedores and marine terminal operators were added which resulted in higher equipment counts, activity and thus, emissions.

Table 5.4: 2023 PHA Cargo Handling Equipment Emissions by Terminal

Terminal	Unit count	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E tonnes
Bayport Terminal	360	92.6	10.8	10.3	7.2	34.5	0.1	38,298
Barbours Cut Terminal	432	190.8	22.6	21.4	15.5	67.1	0.1	36,838
Turning Basin	402	131.4	16.5	16.0	17.3	50.6	0.1	14,550
Care Terminal	56	5.9	0.5	0.5	0.3	2.1	0.0	1,409
Bulk Materials Handling	23	5.1	0.3	0.3	0.3	1.7	0.0	2,129
Industrial Park East	21	5.9	0.8	0.8	0.9	3.1	0.0	1,082
Jacintoport Terminal	141	16.2	1.4	1.4	2.5	8.1	0.0	5,449
Manchester Wharves	144	25.6	2.7	2.6	2.3	10.7	0.0	5,424
PTRA	18	1.1	0.1	0.1	1.3	69.5	0.0	479
Sims Bayou	5	0.3	0.0	0.0	0.0	0.1	0.0	283
Southside Wharves	5	0.2	0.0	0.0	0.0	0.1	0.0	41
Woodhouse	3	0.0	0.0	0.0	0.0	0.0	0.0	8
Total	**1,610**	**475.2**	**55.7**	**53.2**	**47.6**	**247.8**	**0.4**	**105,993**

In 2023, roughly 29-42% percent of the emissions were from Port operated equipment. Table 5.5 provides the summary for PHA operated and tenant operated CHE, while Table 5.6 shows distribution of the port owned and operated equipment emissions by terminal.

Table 5.5: Port Operated and Tenant Operated Cargo Handling Equipment Emissions

Terminal	Unit count	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E tonnes
PHA Port owned equipment	267	192	23	22	14	64	0.2	41,611
PHA Tenant Operated equipment	1,343	284	32	31	34	184	0.2	64,381
Total	**1,610**	**475**	**56**	**48**	**28**	**248**	**0.4**	**105,993**
PHA Operated %	**17%**	**40%**	**42%**	**41%**	**29%**	**26%**	**42%**	**39%**

Table 5.6: Port Operated Cargo Handling Equipment Emissions by Terminal

Terminal	Unit count	NO_x (tons)	PM_{10} (tons)	$PM_{2.5}$ (tons)	VOC (tons)	CO (tons)	SO_x (tons)	CO_2E tonnes
Bayport - PHA operated	123	56.5	6.9	6.5	4.5	19.3	0.07	19,020
Barbours Cut - PHA operated	135	135.0	16.5	15.5	9.2	44.4	0.09	22,537
Turning Basin - PHA operated	9	0.2	0.0	0.0	0.0	0.1	0.00	54
Total	**267**	**191.7**	**23.4**	**22.0**	**13.6**	**63.8**	**0.16**	**41,611**

SECTION SIX

RAILROAD LOCOMOTIVES

SECTION 6 RAILROAD LOCOMOTIVE

This section presents emission estimates for the railroad locomotives emission source category and is organized into the following subsections: emission source description (6.1), data and information acquisition (6.2), emissions estimation methodology (6.3), and the locomotive emission estimates (6.4).

6.1 SOURCE DESCRIPTION

Locomotive operations typically consist of line haul and switching or yard activity. Line haul refers to the movement of cargo over long distances (e.g., cross-country) and occurs within a port, marine terminal, or rail yard as the initiation or termination of a line haul trip, as cargo is either picked up for transport to destinations across the country or is dropped off for shipment overseas. Switching generally refers to the assembling and disassembling of trains, sorting of the railcars of inbound cargo trains into contiguous "fragments" for delivery to recipients and the short distance hauling of rail cargo within a port or rail yard.

Locomotives used for line haul operations are typically powered by diesel engines of over 4,000 horsepower, while switching locomotive engines are smaller, typically producing 1,200 to 3,000 horsepower. Older line haul locomotives have often been converted to switch duty as newer line haul locomotives with more horsepower become available. Locomotive engines are operated in a series of discrete power steps called notches which range from positions one through eight. This differs from the finely adjustable throttle controls used in automobiles and most powered equipment. Many locomotives also have a setting called dynamic braking, which is a means of slowing the locomotive using the drive system.

Locomotive operations included in this inventory are switching and rail yard activities of the Port Terminal Railroad Association (PTRA), and line haul activities of the Class 1 railroads Union Pacific (UP), Burlington Northern Santa Fe (BNSF), and Kansas City Southern (KCS) within the HGB nonattainment area counties.

Formed in 1924, PTRA is currently an association of the three Class 1 railroads listed above, the Port of Houston Authority, and Houston Belt & Terminal Railway Co. The association serves as an interchange between the many terminals and other facilities along the Houston Ship Channel and the Class 1 railroads that move cargo to other parts of the country. The railroad serves a total of 226 public and private customers along both sides of the Ship Channel, primarily moving railcars along a total of 154 miles of track between terminals and nearby rail yards where they are picked up by one of the Class 1 railroads for further transport. They also perform storage and switching services at seven rail yards in the vicinity[14]. In 2023 PTRA moved just over 500,000 railcars between terminals and interchange locations[15].

14 www.ptra.com

15 Information provided by PTRA in support of this study

Figure 6.1 provides an illustration of the area and tracks served by PTRA[16].

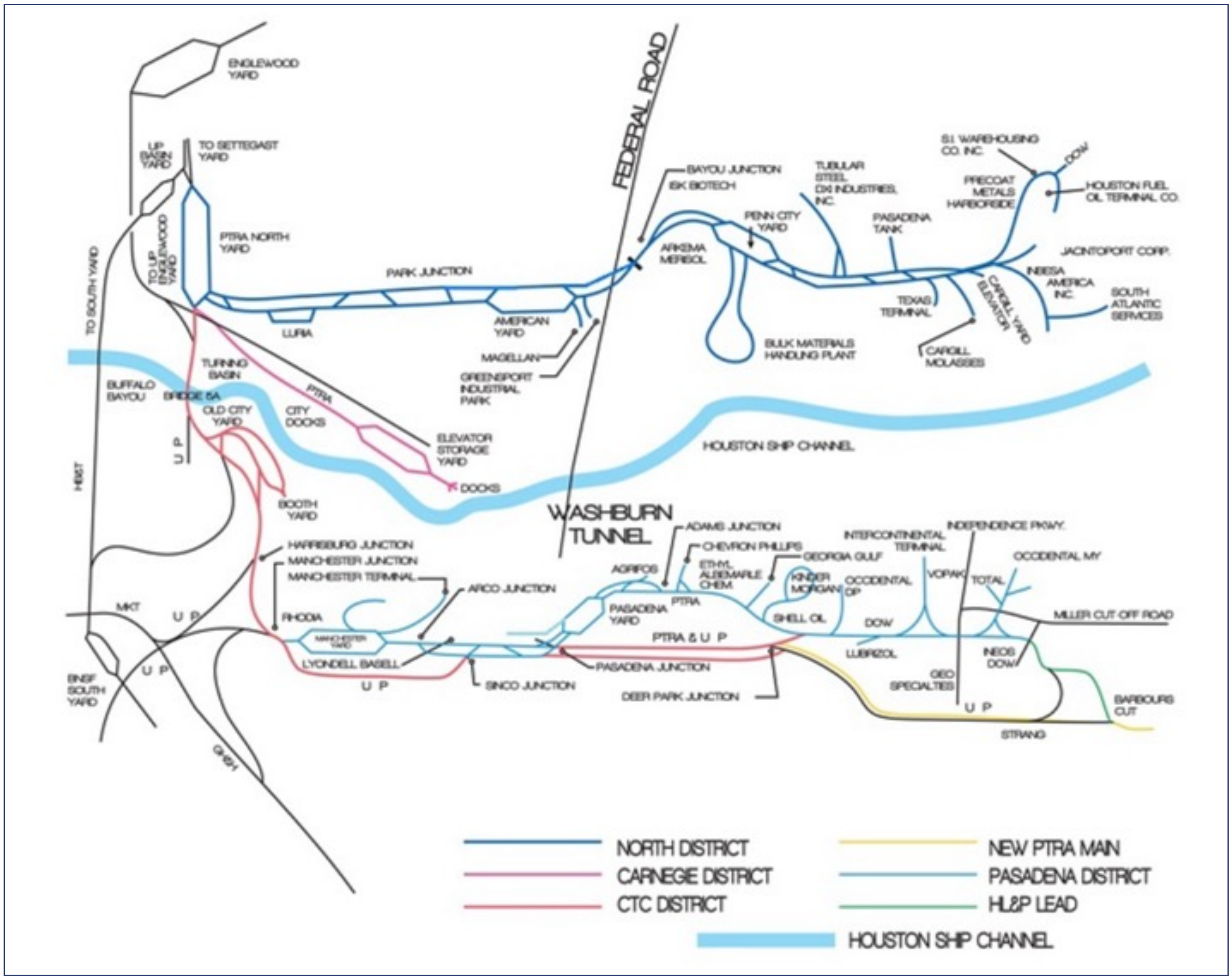


Figure 6.1: PTRA Area Map

The emissions inventory includes locomotive operations associated with Port-related cargo take place at many locations near the Port, including the following PTRA rail yards:

- **North Yard** – *East of Wayside Drive between Market Street and Clinton Drive*
- **Storage Yard** – *South of Clinton Drive, east of Wayside*
- **American Yard** – *South of Market Street on west side of Federal Road*
- **Penn City Yard** – *North side of the Houston Ship Channel south of Jacintoport Blvd. and west of the Beltway 8 Sam Houston Tollway*
- **Manchester Yard** – *Intersection of the east loop of 610 and Manchester Street*
- **Pasadena Yard** – *East of the Washburn Tunnel, north of Red Bluff on the south side of the Houston Ship Channel*

16 www.ptra.com

In addition, Port terminals that have rail connections include the following:

- Bulk Materials Handling Plant – *PTRA*
- Care Terminal – *PTRA*
- Jacintoport – *PTRA*
- Public Elevator No. 2 – *UP*
- Turning Basin Northside – *PTRA*
- Jacob Stern & Sons – *PTRA*
- Empire Terminal – *UP*
- Old Manchester Terminal – *BNSF, KCS, UP*
- Sims Terminal – *PTRA*
- Richardson Steel Terminal – *UP*

The emissions inventory also includes line haul operations conducted by the Class 1 railroads arriving at or departing from a PTRA rail yard or Port terminal within the 8-county HGB area.

6.2 DATA AND INFORMATION ACQUISITION

PTRA provided information on 29 switching locomotives that operate at least some of the time on the PHA railyards. The information provided includes the model, year of manufacture, horsepower, and engine tier level of each locomotive. In addition, PTRA provided annual operating hours for 27 locomotives that typically operate on the PHA terminals. Three other facilities provided information on a total of 7 additional switching locomotives operated at their locations, including model, year of manufacture, horsepower, engine tier level, and estimated annual hours of operation.

For line haul operations, PTRA provided throughput information in the form of total railcar counts for each line haul railroad and, separately, loaded railcar counts by commodity. Throughput information detailing containers and tonnage for PHA was sourced from the PHA General Statistical Data Packet[17]. In addition to this information, one of the Class 1 railroads provided detailed information on the movement of cargo within the eight-county nonattainment area. However, it is not possible to determine the Port-related component of this information, so it was not suitable for use in developing emission estimates.

Further information was obtained from annual reports submitted by the Class 1 railroads to the Surface Transportation Board, a Federal agency that oversees the nation's freight rail system[18]. These annual reports, known as R-1 reports, include operating information such as fuel consumption, train-miles of travel, and ton-miles of freight movements[19]. While not location-specific, the information can be used to develop operating profiles such as the average weights of trains, railcars, and locomotives, average fuel consumption per mile of travel, and average number of railcars per train. These profiles can be developed for each Class 1 railroad and as averages representing a group of railroads. Table 6.1 illustrates the information derived from the 2023 R-1 reports from UP, BNSF, and KCS.

17 Port of Houston Authority, General Statistical Data Packet, see: porthouston.com

18 www.stb.gov/about-stb/

19 www.stb.gov/reports-data/economic-data/annual-report-financial-data/

Table 6.1: Locomotive and Train Characteristics from 2023 R-1 Reports

Characteristic		UP	BNSF	KCS	AVERAGES
Gross ton-miles per gallon of fuel		995	918	598	940
Gallons per thousand GTM		1.005	1.089	1.673	1.064
Gross tons per train	Unit Trains	10,639	10,054	9,089	10,180
	Way Trains	2,405	2,907	2,224	2,631
	Through Trains	8,487	6,302	574	7,108
	All trains	8,562	7,389	4,339	7,746
Locomotives per train	Unit Trains	3.4	3.5	3.0	3.4
	Way Trains	2.0	2.2	2.2	2.1
	Through Trains	3.5	3.4	2.5	3.4
	All trains	3.4	3.3	2.7	3.3
Gross tons per railcar	Unit Trains	83.5	93.5	87.6	89.8
	Way Trains	78.0	167.2	85.7	109.1
	Through Trains	90.3	106.7	7.0	94.8
	All trains	88.0	100.9	51.2	93.1
Average cars per train	Unit Trains	127.4	107.6	103.7	113.4
	Way Trains	30.8	17.4	25.9	24.1
	Through Trains	94.0	59.1	81.5	74.9
	All trains	97.2	73.2	84.7	83.2

6.3 EMISSION ESTIMATION METHODOLOGY

The following provides a description of the methods used to estimate emissions from switching and line haul locomotives operating within the inventory area.

While EPA's MOVES4 model, as described in a preceding section, was used for estimating emissions from non-road equipment such as CHE, the model does not estimate emissions from locomotives.

Fuel usage is converted to horsepower-hours using conversion factors that equate horsepower-hours to gallons of fuel (hp-hr/gal), which represent a property known as brake-specific fuel consumption (BSFC):

EQUATION 6.1

$$\text{Annual work in hphr per year} = \text{gallons/year} \times \text{hphr/gallon}$$

The calculation of emissions from horsepower-hours uses the following equation:

EQUATION 6.2

$$E = (\text{Annual work} \times EF) / (453.59\ g/lb \times 2{,}000\ lb/ton)$$

WHERE:

E = emissions, tons per year

Annual work = annual work, hp-hrs/yr

EF = emission factor, grams pollutant per horsepower-hour

453.59 g/lb x 2,000 lb/ton = tons per year conversion factor

The BSFC value used for the switching locomotive calculations was 15.2 hp-hr/gal, while the value used for the line haul locomotive calculations was 20.8 hp-hr/gal, both from the cited 2009 EPA document.

Table 6.2 summarizes the estimated fuel consumption and horsepower-hours attributed to the switching locomotives operated by PTRA and three terminals that operate switching locomotives on a limited basis within their facilities. The locomotive operators reported estimated annual operating hours for 2023, including 27 PTRA switching locomotives. Cumulative fuel consumption of locomotives in each tier level was calculated by multiplying the hours operated by the fuel consumption rate (7 gallons/hr) and horsepower-hours were calculated using equation 6.1 above.

Table 6.2: Estimated Switching Locomotive Hours, Fuel Consumption, & Horsepower-hours

TIER	HOURS	FUEL gallons	HORSEPOWER hours
Pre-tier	5,200	37,800	574,560
Tier 0	26,342	184,394	2,802,789
Tier 0+	122,197	855,379	13,001,761
Totals	**153,939**	**1,077,573**	**16,379,110**

Table 6.3 presents an annual picture of locomotive and train activity based on the data from the Port and PTR on railcar movements, the information derived from the R-1 reports presented above in Table 6.1, and the BSCF calculation presented in equation 6.1 above. The R-1 information includes fuel consumption rate in gallons per thousand gross ton-miles, average number of railcars and locomotives per train, and average weight of railcars and trains. These values allow calculation of total gross tons which, combined with the estimated distance traveled within the inventory domain, allow the estimation of total gross ton-miles. From this, fuel consumption and horsepower-hours are calculated.

Table 6.3: Estimated Line Haul Train Parameters, Fuel Consumption, & Horsepower-hours

CHARACTERISTIC / PARAMETER	UP	BNSF	KCS	AVG / Totals
Miles in Area	77	79	78	78
Railcars	299,666	193,216	10,893	503,775
Trains	3,082	2,638	129	5,849
Locomotives	10,408	8,815	346	19,570
Gross tons, railcars	26,385,475	19,493,935	557,926	46,437,336
Gross tons, locomotives	2,185,737	1,851,096	72,763	4,109,596
Gross tons, totals	28,571,212	21,345,031	630,689	50,546,932
Gross ton-miles	2,199,983,308	1,686,257,485	49,193,718	3,935,434,512
gals /1,000 gross ton-mile	1.005	1.089	1.673	1.064
Gallons fuel	2,210,983	1,836,334	82,301	4,129,619
Horsepower-hours	**45,988,451**	**38,195,756**	**1,711,863**	**85,896,069**

The EPA emission factors for line haul locomotives cover particulate matter, NO_x, CO, and hydrocarbon (HC) emissions, published as g/gal factors and converted to g/hp-hr using the BSFC value for line haul noted above, while the emission factors for switching locomotives from the same source are published directly as g/hphr. SO_x emission factors have been developed to reflect the use of 15 ppm ULSD using a simplified mass balance approach. This approach assumes that all the sulfur in the fuel is converted to SO_2 and emitted during the combustion process. While the mass balance approach calculates SO_2 specifically, it is a reasonable approximation of SO_x. The following example shows the calculation of the SO_x emission factor for switching locomotives. The calculation for line haul locomotives is identical except for the use of the line haul BSFC value.

EQUATION 6.3

(15 g S)/ (1,000,000 g fuel) × (3,200 g fuel)/(gal fuel) × (2 g SO_2)/(g S) × (gal fuel)/ (15.2 hp hr) = 0.006 g SO_2/hphr

In this calculation, 15 ppm S is written as 15 g S per million g of fuel. The value of 15.2 hp-hr/gallon of fuel is the average BSFC noted in EPA's technical literature on locomotive emission factors (EPA, 2009). Two grams of SO2 are emitted for each gram of sulfur in the fuel because the atomic weight of sulfur is 32 while the molecular weight of SO2 is 64, meaning that the mass of SO2 is two times that of sulfur.

Greenhouse gas emission factors from EPA references [20] have been used to estimate emissions of the greenhouse gases CO2, CH4, and N2O from locomotives. Additionally, all particulate matter emissions are assumed to be PM10. PM2.5 emissions have been estimated as 97% of PM10 emissions to be consistent with the PM2.5 ratio used by MOVES in estimating PM2.5 emissions from other types of nonroad engines.

Table 6.4 lists the emission factors, as g/hp-hr, used in calculating line haul and switching emissions. The line haul emission factors are composites representing the nation-wide fleet of locomotives in 2023 as estimated by EPA. Because line haul locomotives operate over large parts of the country (for example, UP operates in 23 states) and individual locomotives are generally not dedicated to a particular area, the use of a wide area composite is appropriate for estimating emissions from locomotives that operated within the inventory domain.

20 EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, April 2024.

Railroads have historically been reluctant to provide detailed lists of locomotives operating in any particular area given their wide range of operations, so the EPA composites are the best readily available information.

The switching emission factors are listed by emission tier levels, which reflect the level of emission control based on the year of manufacture. The oldest locomotives, manufactured before 1973, are termed "uncontrolled" because no emission control standards were applied to them, while Tier 0 applies to locomotives manufactured between 1973 and 2001 with a basic level of emission control. These tier levels account for the switchers operated by PTRA and the other facilities operating switchers, although stricter standards will apply when these locomotives are rebuilt.

Table 6.4: Emission Factors for Locomotives, g/hp-hr

ACTIVITY / Tier Level	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH4
	g / hphr								
Line haul									
2023 composite	3.79	0.09	0.09	0.14	1.28	0.01	490	0.012	0.038
Switching									
Uncontrolled	16.3	0.44	0.43	1.01	1.83	0.006	670	0.017	0.052
Tier 0	11.8	0.44	0.43	1.01	1.83	0.006	670	0.017	0.052
Tier 0 +	9.9	0.23	0.22	0.6	1.83	0.006	670	0.017	0.052

6.4 LOCOMOTIVE EMISSION ESTIMATES

The estimated line haul and switching emissions are presented in Table 6.5. The NO_x emissions were adjusted to account for the use of TxLED fuel (6.2% reduction). The nature of the activity, fuel consumption, and cargo data underlying the estimates has not allowed more precise geographical allocation of line haul or switching emissions.

Table 6.5: Estimated Emissions from Locomotives

ACTIVITY	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_x	CO_2E
	tons						tonnes
Line haul	358.9	8.6	8.5	13.7	121.2	0.5	42,454
Switching	189	4.9	4.8	12.4	33	0.1	11,072
Totals	**548**	**13.3**	**13.3**	**26.0**	**154**	**0.6**	**53,525**

SECTION SEVEN

HEAVY-DUTY VEHICLES

SECTION 7 HEAVY-DUTY VEHICLES

This section presents emission estimates for the heavy-duty vehicles (HDV) emission source category and is organized into the following subsections: emission source description (7.1), data and information acquisition (7.2), emission estimation methodology (7.3), and the heavy-duty vehicles emission estimates (7.4).

7.1 SOURCE DESCRIPTION

Heavy-duty trucks move cargo to and from the terminals and facilities that serve as the bridge between land and sea transportation. They are primarily driven on the public roads near the port and on highways within the inventory domain as they arrive from or depart to locations outside the domain. The vehicles are usually not under the direct control of the ports, the terminals, or the shippers who use the terminals, but are usually either owner-operated or are components of a carrier fleet. The most common configuration of HDVs in maritime freight service is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles. Common trailer types in the study area include container trailers built to accommodate standard-sized cargo containers, as well as tankers, boxes, and flatbeds.

Figure 7.1: Typical Heavy-duty Trucks

Most truck trips associated with the Port (approximately 84%) are made by container trucks that almost exclusively service two terminals, Barbours Cut Container Terminal and Bayport Container Terminal. Approximately 16% of trips made by non-container trucks are to and from other PHA cargo facilities. The PHA facilities for which truck trips were identified are listed below. Their locations are illustrated in Figure 1.1 of Section 1 of this report.

- **Barbours Cut Container Terminal**
- **Bayport Container Terminal, including:**
  - Bayport Auto Terminal
- **Bulk Materials Handling Plant**
- **Care Terminal**
- **Jacintoport Terminal**
- **Woodhouse, including:**
  - Richardson Steel
  - Public Elevator #2
  - Ardent Mills
- **Turning Basin Terminal gates:**
  - Industrial Park East
  - Cargo Bay Rd
  - Southside 18
  - Jacob Stern & Sons
  - Manchester Terminal
  - Huntsman
- **Sims Bayou**

7.2 DATA AND INFORMATION ACQUISITION

HDV emission estimates are based on the number of miles traveled by the trucks within the inventory domain, which is a function of the number of trips made to and from the Port's terminals and facilities and the distance traveled within the domain on each trip. The other major variables that contribute to the emission estimates are the number of hours the trucks are idling at each terminal and the distribution of model years of the trucks making the trips, since emission standards result in newer trucks emitting lower levels of some pollutants than earlier model year trucks.

Information on the number of truck trips associated with the Port's container terminals was obtained from the Port's gate data system that provides detailed information on trucks entering and leaving the Bayport and Barbours Cut container terminals. In addition to a count of trucks, the data includes model year information that allowed the development of a model year distribution that was used to develop fleet-specific emission factors.

The number of truck trips associated with three major Turning Basin Terminal gates (Cargo Bay Road, Southside Gate 18, and Industrial Park East) was calculated using the truck count data from 2019 and applying growth factors from 2019 to 2023 using cargo throughput data.

Information on truck trips associated with other tenant and PHA facilities was obtained by contacting each facility directly and requesting information on whether their operations included truck traffic and, if so, how many truck visits they had during 2023. Truck visits were estimated for facilities that declined to provide specific numbers by extrapolating from annual cargo throughput information provided by the Port, or from the percentage of trips provided during 2019 GMEI. Table 7.1 lists the reported or estimated number of truck trips associated with each terminal or facility, and the source or method used to arrive at the number of trips.

Table 7.1: Estimated Truck Trip Counts and Data Sources

FACILITY	TRUCKS 2023	DATA SOURCE or Estimated Method
Barbours Cut Container Terminal	1,278,649	PHA Gate Data System
Bayport Container Terminal	1,878,197	PHA Gate Data System
Bayport Auto Terminal	14,400	Estimate from throughput
Bulk Materials Handling Plant	24,387	Estimated by % growth
Care	33,751	Estimated by % growth
Jacintoport	134,899	Estimated by % growth
Woodhouse		
Richardson Steel Terminal	100	Reported by facility
The Andersons (Grain Elev. No. 2)	8,714	Reported by facility
Ardent Mills (flour mill)	11,000	Reported by facility
Turning Basin Terminal		
Industrial Park East (IPE)	52,090	Extrapolated from 2019 survey
Cargo Bay Rd (TBT gate)	283,789	Extrapolated from 2019 survey
Southside 18 (TBT gate)	13,574	Extrapolated from 2019 survey
Jacob Stern and Sons	6,547	Reported by facility
Manchester Wharves	35,632	Estimated by % growth
Huntsman	5,096	Reported by facility
Sims Bayou	1,000	Reported by facility
Totals - container trucks	**3,156,846**	
Totals - non-container trucks	**618,884**	
Totals	**3,775,730**	

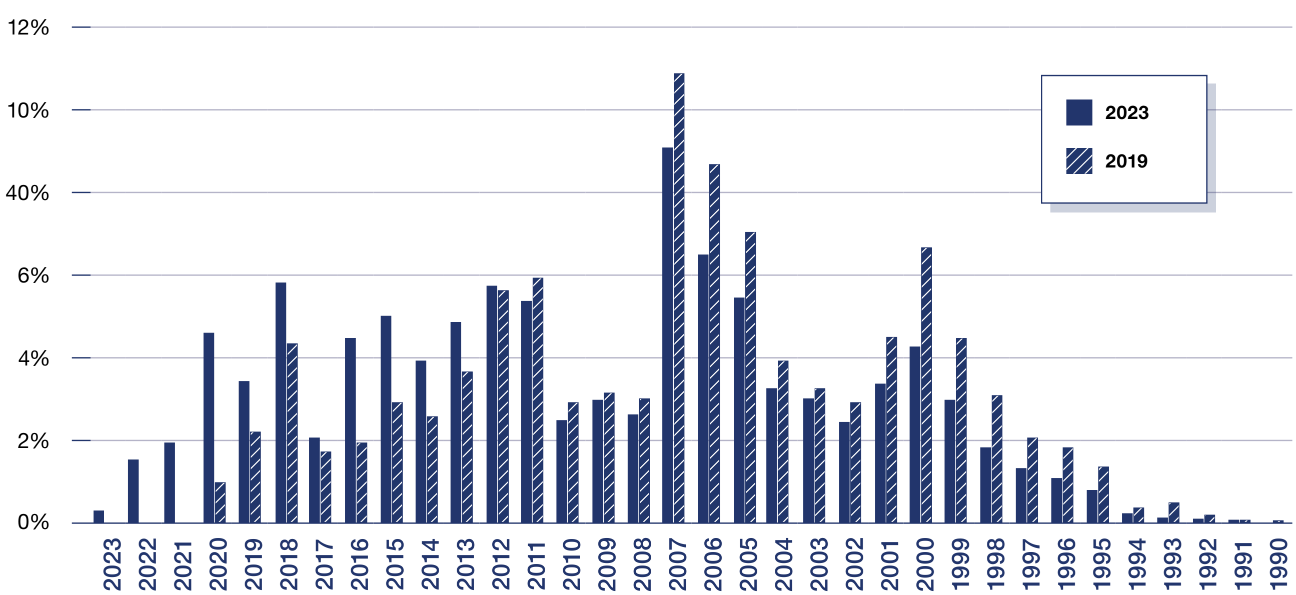
The average on-road distance traveled on each trip has been estimated using road travel distances from a truck mobility study conducted by the Texas Department of Transportation, Houston Division in 2020. The study includes the percentages of truck trips throughout the inventory area (and to the area boundary) that travel from and to four Port terminal areas: Barbours Cut, Bayport, Jacintoport, and Turning Basin. The study presented the results of two different surveys which were averaged for the PHA GMEI. To calculate average trip distances for this inventory, the distances between the Port terminal areas and various zones within the inventory area (and to the area boundary) were estimated and weighted average trip distances were calculated for each Port terminal area. For this 2023 GMEI, the distances used in 2019 GMEI remained the same.

Another component of travel distance is the distance traveled while the trucks are within the terminal or facility boundaries. Part of the data collection process was asking facility operators how far, on average, trucks travel while within the facility boundaries. Other on-terminal distances were estimated by evaluating gate-to-gate distances using online measuring tools such as "Google Earth[21]."

In addition to VMT, another component of truck operations that results in emissions is idling in place, such as when waiting to unload or load cargo. The emission factors for on-road travel include idling that is incidental to routine driving but idling for longer periods is not included. Truck engines can idle while waiting in line, referred to as short-term idling (queueing). Trucks can also idle for extended periods of time, when the engine power is needed to run heating or cooling for driver safety or comfort, referred as extended idling. Emissions have been estimated for short-term idling at the facilities to account for wait times on loading and unloading. Similar to the prior GMEIs, an estimated 40 minutes of idling time per truck visit is used for locations with unknown idling time.

The truck model year distribution is important to the development of emission estimates. The 2023 gate moves data for the Bayport and Barbours Cut container terminals provided model year information on the trucks calling at those terminals from which the distribution of model years was developed. Truck calls to and from these container terminals accounted for 84% of truck calls. The same distribution of truck model years was used for the remaining "non-container" terminals. Figure 7.2 compares the 2023 and 2019 container truck model year distributions. The newest model year is to the left with trucks of progressively older model years displayed to the right. The 2023 distribution shows that newer trucks are present in the 2023 distribution and there are lower fractions of older trucks. The shift towards newer and cleaner trucks helped with the 2023 truck emissions.

Figure 7.2: Comparison of 2023 and 2019 Truck Model Year Distributions



21 www.google.com/earth/

7.3 EMISSION ESTIMATION METHODOLOGY

In general, emissions from HDVs are estimated using the general equation.

EQUATION 7.1

$$E = EF \times A$$

WHERE:

E = mass of emissions per defined period (such as a year)

EF = emission factor (mass per unit of distance or time)

A = activity (distance driven, or time at idle, during the defined period)

Emissions are estimated by multiplying the emission factor by the miles driven or the hours of idling time. The units of distance in this inventory are miles, the idling units are hours, and the emission factors are expressed as grams of emissions per mile of travel (g/mile) or grams of emissions per hour of idling (g/hr). Annual emissions are expressed in short tons for the criteria pollutants and metric tons (tonnes) for greenhouse gases.

The emission factors have been developed using the EPA model MOVES4, which estimates emissions and emission factors for on-road vehicles of all types, including HDVs. The MOVES4 model is EPA's latest iteration in a series of on-road vehicle emission estimating models. The model can be run in such a way as to produce emission estimates for each model year of the specified vehicle types in a given state/county combination, and the estimated total activity for the vehicles in the county. These model outputs are used to calculate g/mile and g/hr emission factors by dividing total grams of emissions by total miles traveled or by total hours of idling.

The resulting emission factors are applicable to individual vehicle model years. Composite emission factors are calculated by multiplying and summing each vehicle model year's emission factor for a given pollutant by the fraction of that model year in the model year distribution. The composite emission factors are also in units of g/mile and g/hr and are used to estimate on-terminal and on-road driving emissions and on-terminal idling emissions.

The MOVES4 model was run in the modes: on-road travel, on-terminal idling and low speed travel. For on-road travel within the inventory domain, the model was run in default scale, producing annual emissions and mileage for each road type, vehicle type, and model year, using the model's own data related to average road speeds. The model was run for truck type 61, "combination short-haul," using diesel fuel, for road types "urban restricted access" and "urban unrestricted access."

For on-terminal travel and idling, the model was run in project scale, defining 15-mph and idling links at a one-hour time scale. The model's design dictates that idling emissions are estimated for single hours rather than a one-year period, so the model was run for a January morning hour and a July afternoon hour to cover the range of typical temperature conditions, and the results of the two runs were averaged to estimate average hourly low-speed driving emissions and idling emissions. Table 7.2 summarizes the model parameters used to develop the emission factors, as summarized above.

PORT HOUSTON
THE INTERNATIONAL PORT OF TEXAS

Table 7.2: MOVES4 Model Parameters

Parameter / Pollutant	Values used in model runs*			
Time Scale for On-Road	Annual, 2023			
Time Scale for On-Terminal	Two one-hour periods, 9:00 am in January averaged with 4:00 pm in July			
Vehicle Type	Combination short-haul truck			
Fuel Type	Diesel			
Road Types for On-Road	Urban restricted access and urban unrestricted access			
Road Type for On-Terminal	Urban unrestricted access			
Pollutants & Processes	**Running exhaust**	**Crankcase running**	**Start exhaust**	**Crankcase start**
▪ Total gaseous hydrocarbons	X	X	X	X
▪ Non-methane hydrocarbons	X	X	X	X
▪ Non-methane organic gases	X	X	X	X
▪ Total organic gases	X	X	X	X
▪ Volatile organic compounds	X	X	X	X
▪ CH_4	X	X	X	X
▪ CO	X	X	X	X
▪ NO_x	X	X	X	X
▪ N_2O	X	X	X	X
▪ Primary exhaust PM_{25}	X	X	X	X
▪ Primary exhaust PM_{25} species	X	X	X	X
▪ Primary exhaust PM_{10} total	X	X	X	X
▪ SO_2	X	X	X	X
▪ Total energy consumption	X	---	X	---
▪ Atmospheric CO_2	X	---	X	---

* "X" adjacent to pollutant name indicates included in model run

Table 7.3 lists the emission factors developed from the model output files that have been used to estimate emissions.

Table 7.3: Emission Factors for HDVs, grams/mile and grams/hour

TRUCK TYPE	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2	N_2O	CH_4
					g/mi or g/hr				
Container trucks									
On-road (g/mi)	7.5	0.30	0.28	0.5	2.8	0.006	1,746	0.024	0.125
On-terminal (g/mi)	10.9	0.43	0.40	0.6	5.0	0.008	2,360	0.055	0.207
On-terminal idling (g/hr)	54.0	2.55	2.34	4.9	20.3	0.026	7,769	0.360	0.715
Non-container trucks									
On-road (g/mi)	7.5	0.30	0.28	0.5	2.8	0.006	1,746	0.024	0.125
On-terminal (g/mi)	10.9	0.43	0.40	0.6	5.0	0.008	2,360	0.055	0.207
On-terminal idling (g/hr)	54.0	2.55	2.34	4.9	20.3	0.026	7,769	0.360	0.715

7.4 HEAVY-DUTY VEHICLES EMISSION ESTIMATES

The estimated emissions from on-road travel throughout the inventory domain, and on-terminal slow-speed driving and idling, are presented in Tables 7.4 through 7.7. Table 7.4 presents a summary of all emissions. The NOx emissions have been adjusted to account for the use of TxLED fuel (6% reduction).

Table 7.4: Estimated Emissions from HDVs, tons and tonnes

ACTIVITY LOCATION	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
On-terminal (driving and idling)	199	9.3	8.5	16.0	88	0.1	35,223
On-road within inventory domain	1,173	50.2	46.2	77.0	460	1.0	269,296
Totals	**1,372**	**59.5**	**54.7**	**93.1**	**548**	**1.1**	**304,519**

Table 7.5 presents the on-terminal emissions by facility.

Table 7.5: Estimated On-Terminal Emissions from HDVs, tons and tonnes

FACILITY	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
Barbours Cut Container Terminal	72.9	3.4	3.2	6.1	31.8	0.05	12,466
Bayport Container Terminal	100.8	4.7	4.3	8.0	45.1	0.07	18,171
Bayport Auto Terminal	0.7	0.0	0.0	0.1	0.3	0.00	117
Bulk Materials Handling Plant	0.9	0.0	0.0	0.1	0.4	0.00	157
Care Terminal	1.0	0.1	0.0	0.1	0.4	0.00	169
Jacintoport Terminal	3.9	0.2	0.2	0.4	1.6	0.00	615
Woodhouse Terminal	.3	0.0	0.0	0.0	0.1	0.0	50
Turning Basin Terminal	15.1	0.7	0.6	1.1	7.0	0.0	2,928
Industrial Park East	1.9	0.1	0.1	.2	0.8	0.0	335
Manchester Wharves	1.2	0.1	0.1	0.1	0.5	0.0	213
Sims Bayou	0.0	0.0	0.0	0.0	0.0	0.0	5
Total	**198.9**	**9.3**	**8.5**	**16.0**	**88.2**	**0.1**	**35,223**

Table 7.6. presents the on-terminal driving emissions by terminal.

Table 7.6: Estimated On-Terminal Driving Emissions from HDVs, tons and tonnes

FACILITY	Driving Emissions						
	NO_X (tons)	PM_{10} (tons)	PM_{25} (tons)	VOC (tons)	CO (tons)	SO_2 (tons)	CO_2E (tonnes)
Barbours Cut Container Terminal	28.9	1.2	1.1	1.8	14.1	0.02	6,179
Bayport Container Terminal	53.0	2.2	2.1	3.3	26.0	0.04	11,346
Bayport Auto Terminal	0.2	0.0	0.0	0.0	0.1	0.00	52
Bulk Materials Handling Plant	0.4	0.0	0.0	0.0	0.2	0.0	89
Care Terminal	0.3	0.0	0.0	0.0	0.1	0.00	61
Jacintoport Terminal	0.8	0.0	0.0	0.0	0.4	0.0	163
Woodhouse Terminal	0.1	0.0	0.0	0.0	0.0	0.0	12
Turning Basin Terminal	10.6	0.5	0.4	0.7	5.2	0.0	2,292
Industrial Park East	0.9	0.0	0.0	0.1	0.4	0.00	189
Manchester Wharves	0.5	0.0	0.0	0.0	0.2	0.00	108
Sims Bayou	0.0	0.0	0.0	0.0	0.0	0.00	1
Total - Driving	**95.7**	**4.1**	**3.7**	**6.0**	**46.8**	**0.1**	**20,494**

Table 7.7 presents the idling emissions by terminal.

Table 7.7: Estimated On-Terminal Idling Emissions from HDVs, tons and tonnes

FACILITY	Idling emissions						
	NO_X (tons)	PM_{10} (tons)	PM_{25} (tons)	VOC (tons)	CO (tons)	SO_2 (tons)	CO_2E (tonnes)
Barbours Cut Container Terminal	44.0	2.2	2.0	4.3	17.7	0.02	6,286
Bayport Container Terminal	47.8	2.4	2.2	4.6	19.2	0.02	6,824
Bayport Auto Terminal	0.5	0.0	0.0	0.0	0.2	0.0	64
Bulk Materials Handling Plant	0.5	0.0	0.0	0.0	0.2	0.0	68
Care Terminal	0.8	0.0	0.0	0.1	0.3	0.0	108
Jacintoport Terminal	3.2	0.2	0.1	0.3	1.3	0.0	451
Woodhouse Terminal	0.3	0.0	0.0	0.0	0.1	0.0	38
Turning Basin Terminal	4.5	0.2	0.2	0.4	1.3	0.0	636
Industrial Park East	1.0	0.1	0.0	0.1	0.4	0.0	145
Manchester Wharves	0.7	0.0	0.0	0.1	0.3	0.0	105
Sims Bayou	0.0	0.0	0.0	0.0	0.0	0.0	3
Total - Driving	**103.2**	**5.2**	**4.8**	**10.0**	**41.4**	**0.1**	**14,729**

SECTION EIGHT

COMPARISON OF 2023 & 2019 EMISSIONS ESTIMATES

SECTION 8 COMPARISON OF 2023 & 2019 EMISSION ESTIMATES

This section provides a comparison of the PHA emission estimates for 2023 and 2019 by source category. Calculation methodologies were updated for most of the emission source categories based on the latest EPA Ports Emissions Inventory Guidance published April 2022 and the updated EPA emissions model, MOVES4, which is used for nonroad equipment and trucks.

In addition, when comparing to 2019, emission changes are based on various other factors including activity and operational differences, fleet turnover, different fleet mix, improvements in methodology as new information is made available, compliance with regulations, efficiency, and implementation of emission reduction strategies. This section will explain those changes at a high level for each source category.

Wherever possible, the 2019 emissions were re-calculated using the latest methodologies or otherwise adjusted to account for the changes to produce a more meaningful comparison. This approach minimizes the impact of methodological differences and enables a high-level discussion of the changes in emissions resulting from activity changes and implemented emission reduction strategies that occurred. The 2019 OGV emissions were re-calculated to consider improvements in AIS data analysis methodology for speed and distances and harmonizing the classification of MAN engines for slide valves. Therefore, the 2019 OGV emissions listed in this report are not the same as those published in the 2019 report. The 2019 CHE emissions were also recalculated to use the latest MOVES4 output. For all source categories, GHG emissions were recalculated to consider the latest global warming potential (GWP) factors.

8.1 PHA EMISSIONS COMPARISON

Table 8.1 provides a comparison of cargo volumes in short tons and container throughput for PHA terminals only. Compared to 2019, cargo volumes and container throughput in TEU for 2023 were 16% and 28% higher, respectively. The increased container throughput is due to continued modernization of PHA's Barbours Cut and Bayport Terminals that has helped increase cargo handling efficiency and capacity. Post-pandemic consumerism is also a reason for the increased container cargo volume seen at PHA.

Table 8.1: PHA Cargo Volumes Comparison

YEAR	CARGO (short tons)	CONTAINERS TEU
2023	50,323,264	3,826,157
2019	43,235,690	2,990,175
Change (%)	**16%**	**28%**

Table 8.2 presents the total net change in PHA emissions by source category in 2023 compared to 2019. The PHA emissions were lower for certain source categories and for certain pollutants. The emission changes were not the same across the board as in prior years. This is due to a combination of increased throughput which will increase activity and as a result emissions, but there is also a transition to newer engines that have lower NOx and PM engine standards. The emission changes for each source category are discussed in more detail in sections 8.3 to 8.7.

Table 8.2: PHA Emissions Comparison, tons, metric tons and %

	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
2023							
Ocean-going vessels	4,536	70	65	143	365	178	268,613
Commerical harbor vessels	103	3	3	3	32	0.1	12,136
Cargo handling equipment	475	56	53	48	248	0.4	105,993
Locomotives	548	14	13	26	154	0.6	53,525
Heavy-duty vehicles	1,372	60	55	93	548	1.1	304,519
Total	**7,034**	**202**	**188**	**313**	**1,348**	**180**	**744,786**
2019							
Ocean-going vessels	4,730	72	67	148	370	183	276,730
Commerical harbor vessels	496	12	12	12	113	0.4	39,805
Cargo handling equipment	365	41	39	36	138	0.3	72,159
Locomotives	587	16	16	27	153	0.6	53,329
Heavy-duty vehicles	1,395	70	64	96	498	0.9	233,748
Total	**7,573**	**211**	**197**	**319**	**1,272**	**185**	**675,771**
Change between 2023 and 2019 (percent)							
Ocean-going vessels	-4%	-3%	-3%	-4%	-1%	-3%	-3%
Commerical harbor craft	-79%	-78%	-78%	-77%	-72%	-69%	-70%
Cargo handling equipment	30%	36%	36%	31%	79%	42%	47%
Locomotives	-7%	-14%	-16%	-2%	1%	-1%	0%
Heavy-duty vehicles	-2%	-14%	-14%	-3%	10%	25%	30%
Total	**-7%**	**-4%**	**-4%**	**-2%**	**6%**	**-3%**	**10%**

8.2 NON-PHA EMISSIONS COMPARISON

The OGV and commercial harbor vessels emissions for non-PHA entities in the Houston Ship Channel are included in Table 8.3 emissions. The 2019 OGV emissions were re-estimated using improved 2023 methodology so they do not match the published numbers in 2019 GMEI.

Table 8.3: Non-PHA Emissions Comparison by Source Category

	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
2023							
Ocean-going vessels	7,211	166	152	240	706	431	651,974
Commerical harbor vessels	5,136	116	112	150	1,112	5	468,522
Total	**12,347**	**281**	**265**	**390**	**1,818**	**436**	**1,120,496**
2019							
Ocean-going vessels	8,209	175	161	253	726	455	688,351
Commerical harbor vessels	3,816	88	85	93	847	3	302,443
Total	**12,025**	**263**	**246**	**346**	**1,573**	**458**	**990,794**
Change between 2023 and 2019 (percent)							
Ocean-going vessels	-12%	-5%	-5%	-5%	-3%	-5%	-5%
Commerical harbor craft	35%	31%	31%	62%	31%	55%	55%
Total	**3%**	**7%**	**7%**	**13%**	**16%**	**-5%**	**13%**

Below are some activity impacts to non-PHA emissions that help explain the emission changes between 2023 and 2019 for OGV and harbor craft:

- The Houston Ship Channel (HSC) is being widened by 170 feet in a phased approach. Dredging began in 2022 to also deepen the channel which will result in larger vessels and less waiting time. The project is expected to be completed in 2029, so the 2023 vessel activity was impacted slightly by this project on segments completed.
- In 2023, there were 317 vessels with Tier III propulsion engines that called non-PHA entities, including 309 tankers, one general cargo vessel and one bulk vessel. NOx emissions from Tier III vessels are 75% lower than from Tier II vessels when operating at or above 25% main engine load. This was a tenfold increase from 2019 and a reason for the vessel's lower NOx emissions in 2023.
- In 2023, there were eight alternatively fueled vessels; 5 that used LNG and 3 that used methanol resulting in lower NOx and PM emissions compared to vessels using diesel fuel.
- For commercial harbor craft, the emissions increased for all pollutants due to increased activity. The articulated tug barge activity is included mainly in the harbor craft activity for 2023 which increased the harbor craft vessel count and activity for 2023 as compared to 2019. There were increased towboat movements in 2023 due to the continued demand of liquid bulk exports.

8.3 PHA OCEAN-GOING VESSELS

Table 8.4 provides a comparison for PHA OGV emissions. The PHA OGV emissions in 2023 are similar to the emissions in 2019.

Table 8.4: PHA OGV Emissions Comparison

YEAR	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
2023	4,536	70	65	143	365	178	268,613
2019	4,730	72	67	148	370	183	276,730
Change (%)	**-4%**	**-3%**	**-3%**	**-4%**	**-1%**	**-3%**	**-3%**

Major highlights for PHA that impacted PHA OGV emissions in 2023 as compared to 2019:

- The overall vessel movements decreased 5% for PHA terminals in 2023 as compared to 2019, despite an increase in TEU throughput and containership calls. The reduced number of total vessel calls resulted in lower OGV emissions.
- In 2023, there were 33 vessels with Tier III propulsion engines that called PHA terminals. In 2019, there were only four vessels. NOx emissions from Tier III vessels are 75% lower than from Tier II vessels when operating at or above 25% main engine load.

Table 8.5: PHA OGV Activity Comparison

YEAR	ARRIVALS	DEPARTURES	SHIFTS	TOTAL
2023	2,342	2,177	763	5,282
2019	2,500	2,311	748	5,559
Change (%)	**-6%**	**-6%**	**2%**	**-5%**

8.4 PHA COMMERCIAL HARBOR CRAFT

Table 8.6 presents the PHA harbor craft emissions comparison. Although there was more vessel activity in 2023 than in 2019, the significant reduction is due to the transition to cleaner engines and less time spent in the area by the vessels.

Table 8.6: PHA Commercial Harbor Craft Emissions Comparison

YEAR	NO_x (tons)	PM_{10} (tons)	PM_{25} (tons)	VOC (tons)	CO (tons)	SO_2 (tons)	CO_2E (tonnes)
2023	103	3	3	3	32	0.1	12,136
2019	496	12	12	12	113	0.4	39,805
Change (%)	**-79%**	**-78%**	**-78%**	**-77%**	**-72%**	**-69%**	**-70%**

8.5 PHA CARGO HANDLING EQUIPMENT

Table 8.7 shows the emissions comparison for Port owned and operated cargo handling equipment located at Barbours Cut, Bayport and Turning Basin Terminals. There are 17% more pieces of equipment in 2023 than in 2019 which accounted for the increase in emissions. Certain equipment usage was higher due to increased cargo throughput. Figure 8.1 shows the hours comparison for several equipment that had higher hours of use in 2023 which resulted in overall higher hours in 2023 than in 2019.

Table 8.7: PHA Operated CHE Emissions Comparison, tons, metric tons and %

YEAR	UNIT count	NO_x (tons)	PM_{10} (tons)	PM_{25} (tons)	VOC (tons)	CO (tons)	SO_2 (tons)	CO_2E (tonnes)
2023	267	192	23	22	14	64	0.2	41,611
2019	229	170	20	19	12	58.9	0.1	30,284
Change	**38**	**22**	**3**	**3**	**1**	**5**	**0.0**	**11,327**
Change (%)	**17%**	**13%**	**17%**	**17%**	**12%**	**8%**	**33%**	**37%**

Figure 8.1: Comparison of 2023 and 2019 Annual Hours of Use

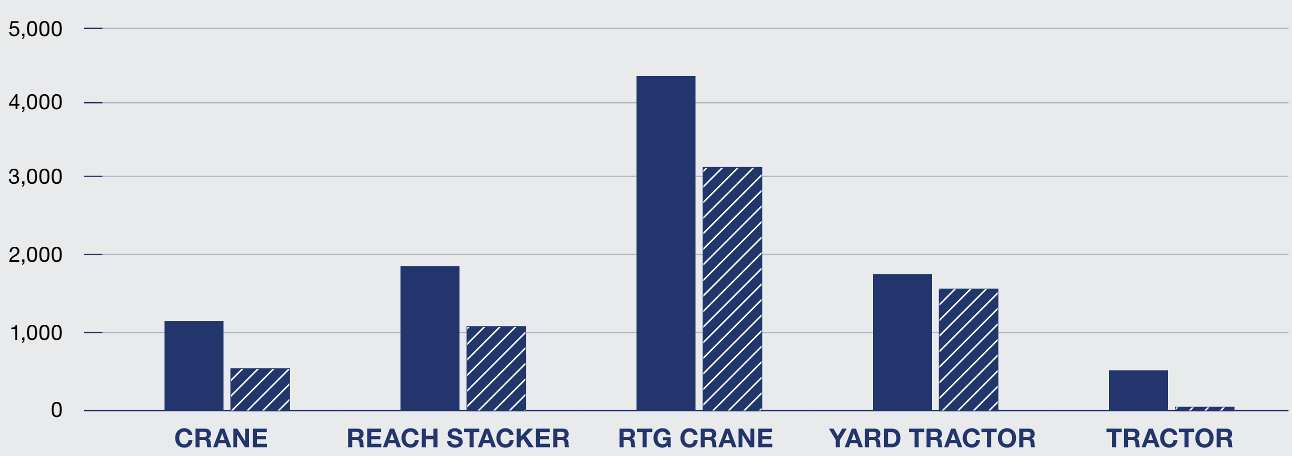


Table 8.8 shows the total cargo handling equipment (port-owned and tenant-owned) emissions comparison. The emissions are higher for all pollutants in 2023 due additional facilities and tenants included which increased the total equipment count and activity. The 2019 emissions were re-estimated using the latest methodology. There are 21% more equipment in 2023 than in 2019. In addition, the equipment had higher hours of use in 2023 (see Figure 8.1) which resulted in even higher emissions.

Table 8.8: Total CHE Emissions Comparison, tons, metric tons and %

YEAR	UNIT count	NO_X	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E tonnes
		tons						
2023	1,610	475	56	53	48	248	0.4	105,993
2019	1,330	365	41	39	36	138	0.3	72,159
Change	**280**	**110**	**15**	**14**	**11**	**109**	**0**	**33,834**
Change (%)	**21%**	**30%**	**36%**	**36%**	**31%**	**79%**	**42%**	**47%**

Table 8.9 shows the distribution of energy consumed, in kilowatt hours, by diesel engine tier. It shows that the newer (Tier 3-4) equipment with the lowest engine standard accounted for almost 72% of the energy consumption for 2023 compared to 65% in 2019. Tier 4 engines were phased in and therefore there are two levels listed: interim (int) and final (fin).

Table 8.9: Diesel Equipment Engine Standard Comparison

ENGINE Type & Tier	ENERGY Consumption kWh	PERCENT Total 2023	PERCENT Total 2019
Alternative fuel	821,264	0.6%	0.5%
Diesel Tier 0	5,748,188	4.2%	3.5%
Diesel Tier 1	6,834,448	5.0%	6.1%
Diesel Tier 2	25,970,826	18.8%	25.1%
Diesel Tier 3	25,372,927	18.4%	21.1%
Diesel Tier 4 int	9,221,028	6.7%	7.2%
Diesel Tier 4 fin	64,019,269	46.4%	36.4%
Total	**137,987,950**	**100.0%**	**100.0%**

8.6 RAILROAD LOCOMOTIVES

Table 8.10 shows the emission comparison for locomotives, including line haul and switching emissions. Overall, locomotive emissions decreased for the majority of pollutants with no significant emission change for CO_2e and a slight increase in CO. The changes in emissions are mainly due to the decrease in line haul locomotive and an increase in switching locomotive activity. For 2023, there were 27 PTRA switching locomotives working as compared to 13 included in 2019.

Table 8.10: Locomotives Emissions Comparison, tons, metric tons and %

YEAR	NO_X	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
2023	548	14	13	26	154	0.6	53,525
2019	587	16	16	27	153	0.6	53,329
Change (%)	**-7%**	**-14%**	**-16%**	**-2%**	**1%**	**-1%**	**0%**

Table 8.11 shows the line haul rail locomotive activity in million gross ton miles, shown as million GTM, of cargo moved in 2023 and 2019 which shows a 12% decrease in 2023 as compared to 2019.

Table 8.11: Line Haul Locomotive Activity, MGTM

YEAR	Million GTM
2023	3,935
2019	4,467
Change (%)	**-12%**

8.7 HEAVY-DUTY VEHICLES

Table 8.12 compares the heavy-duty vehicles count and vehicle miles traveled for 2023 and 2019. In 2023, the truck calls increased by 35% and vehicle miles traveled increased by 32%. The increase is due to the increase in throughput for PHA and the region.

Table 8.12: HDV Count and Vehicle Miles Traveled

YEAR	Million GTM	Vehicle Miles TRAVELED
2023	3,781,826	151,332,781
2019	2,862,153	114,371,215
Change (%)	**32%**	**32%**

Table 8.13 shows the comparison of emissions for heavy-duty vehicles. The 2023 heavy-duty vehicle emissions decreased for most pollutants, except CO, SOx and CO2e. The transition to newer fleet accounts for the decreases in emissions of NOx, PM, and VOCs. The increase in tuck calls and VMT account for the increase in emissions for SOx and CO2e. The newer engines do not have CO emissions reductions to the same degree as NOx and PM, therefore the 10% increase for CO.

Table 8.13: HDV Emissions Comparison, tons, metric tons and %

YEAR	NO_x	PM_{10}	PM_{25}	VOC	CO	SO_2	CO_2E
	tons						tonnes
2023	1,372	59.5	54.7	93.1	548	1.1	304,519
2019	1,395	69.5	64.0	96.2	498	0.9	233,748
Change (%)	**-2%**	**-14%**	**-14%**	**-3%**	**10%**	**25%**	**30%**

SECTION NINE

CONCLUSION & RECOMMENDATIONS

SECTION 9 CONCLUSION & RECOMMENDATIONS

Between 2023 and 2019, Port Houston saw growth in container cargo volume. For PHA facilities alone, cargo throughput increased by 28% in container TEU throughput over the period. The NOx and PM emissions remained unchanged with an increase in CO, hydrocarbons and CO_2e for PHA terminals. The emissions increase is primarily due to increased activity for OGV, trucks and cargo handling equipment. The NOx and PM emissions were offset by the transition to cleaner engines with lower engine standards.

With respect to total emissions for non-PHA sources, commercial harbor craft emissions increased in 2023 due to the increased tugboat and towboat activity in the Houston Ship Channel.

LOOKING AHEAD

Looking into the future, the PHA and Houston Ship Channel facilities continue to grow as reflected in 2024 vessel activity and throughput. The growth is fueled by consumerism and the investments made to the terminals and ship channel deepening and widening project which allows for larger vessels and also more activity in the region. With this growth and increased activity, we expect NOx and CO_2e emissions to increase in the future as compared to 2023. We also expect to continue to see larger vessels, specifically tankers and containerships, call PHA and the Houston Ship Channel. Depending on vessel type and future fleet mix, the ocean-going vessels' emissions may decrease overall due to fewer vessel calls as a result of the larger vessels. Whether there is an increase or decrease will depend on the future vessel fleet mix and time spent at berth, which is difficult to predict. Although activity may continue to increase in the future for most emission source categories, some of the emission increases may be offset by fleet turnover as seen with this inventory.

RECOMMENDATIONS

Since Port Houston is still expanding, a future emissions inventory is recommended every three to five years. The ocean-going vessel inventory is especially crucial to understanding the changes in activity counts, vessel movements and types of tankers that call the Port. The other emission source categories are also important as operations may change, causing effects that are hard to predict. Comparing emissions every few years will ensure that the emission reduction strategies the Port has undertaken over the recent years are adequately taken into consideration in the emissions comparison.

Natural attrition is occurring for commercial harbor craft as vessel operators update their vessel fleet.

For CHE, it is recommended that the Port and its stevedores continue to replace equipment with newer Tier 4 engines and purchase or retrofit equipment with hybrid technology, when possible. The continued use of hybrid equipment and newer engines will provide a positive impact in emissions.

Line haul locomotive emissions may lower with fleet turnover in the future, although activity increases may overshadow any emission reductions achieved through fleet turnover. Advancements in emission standards for trucks have come earlier than for locomotives. This means that current truck fleet emissions may provide lower transportation emissions than rail transport by the current line haul locomotive fleet, but this will vary greatly by pollutant and careful analysis would be required to establish which mode is "cleaner" and by which pollutants.

In addition, ports typically have little to no ability or leverage to influence the locomotive fleet mix of the Class 1 railroads, which make up most of the locomotive emissions in the port setting. The locomotives operated locally by PTRA and other entities now include Tier 0+ locomotives.

HDV emission reductions due to fleet turnover can be accelerated by active measures such as incentive programs to encourage replacement of older trucks and progressive restrictions on the oldest model years that are authorized to operate on Port terminals. If successful, these types of measures can result in fairly rapid emission reductions. PHA has seen success in trucks transitioning to cleaner trucks and will continue in the coming year.

PORT HOUSTON™

THANK YOU